BELL TELEPHONE QUARTERLY

VOL. XIX JANUARY, 1940 NO. 1

A QUARTER CENTURY OF TRANSCONTINENTAL TELEPHONE SERVICE

I. The Line and the Laboratory
II. The Circuits Go Up
III. Transcontinental Panorama

OUR EXHIBITS AT TWO FAIRS

I. At the New York World's Fair
II. At the Golden Gate Exposition

AMERICAN TELEPHONE & TELEGRAPH CO. • NEW YORK

BELL TELEPHONE QUARTERLY

A Medium of Suggestion

A Record of Progress

VOL. XIX JANUARY, 1940 NO. 1

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"A CONTINENT IS BRIDGED"

Drawn by Franklin Booth for the observance of the twenty-fifth anniversary of transcontinental telephone service

A QUARTER-CENTURY OF TRANSCONTINENTAL TELEPHONE SERVICE

The Twenty-fifth Anniversary of the Public Opening of the First Telephone Line from Coast to Coast Recalls the History of that Pioneer Undertaking, and the Great Advances Since Then

INTRODUCTION

ON January 25, 1915, the first transcontinental telephone line was opened for public use. For the 3,400 miles of its cross-country march between New York and San Francisco, it consisted almost wholly of two physical circuits of heavy copper wire and one phantom circuit.

Today the number of circuits—physical and carrier-current—which cross mountains, plains, and deserts between East and West is about 170. They follow four geographically distinct routes. Over them speed many hundreds of messages each day. The service is accepted as a matter of course, and the plant which makes it possible is taken for granted. But it was the First Transcontinental which proved triumphantly that telephony could span the continent; that the ideal of universal service could become a reality.

That is why that date late in January of twenty-five years ago has so vital a significance today. That is why this issue of the QUARTERLY is devoted in such large part to a consideration of the event: of what led up to it and of what has come after; so that it may be seen as epochal, and so that there may be seen a progress and a growth in every phase of telephone service since then which has been as epoch-making as was that first conquest of the barriers to speech between the Atlantic and the Pacific.

The story of the First Transcontinental has never been told in full perspective. The Bell System publications which, a quarter-century ago, first reproduced a number of the illustrations shown here on later pages, are yellowed with time, and but a few thousand remain of the telephone men and women who thrilled then to read how the voices of Bell and Watson, of Vail and Carty and Woodrow Wilson and others, sped by wire across our land.

Indeed, of today's quarter of a million Bell System employees, perhaps ten per cent—perhaps a few more than that—were actively engaged in telephone work in 1915. To some of these, the articles which follow will have the deep interest of personal experience recalled. Others of them, reading of the events here related, will

THE FINAL POLE

On June 17, 1914, the last pole of the transcontinental line was placed at the Nevada-Utah state line and the wires were strung. The men in the picture, reading from left to right, are: C. R. Cole, Superintendent of Construction, Pacific Telephone and Telegraph Company; Mr. Putnam, Special Inspector, American Telephone and Telegraph Company; C. E. Fleager, Division Plant Engineer, Pacific Co.; W. T. Teague, Division Superintendent of Plant, Pacific Co.; D. P. Fullerton, General Superintendent of Plant, Pacific Co.; G. E. McCarn, General Superintendent of Plant, Mountain States Telephone and Telegraph Company; W. D. Staples, Division Superintendent of Plant, A. T. & T. Co.; E. F. Coyer, Mountain States Co.; C. C. Pratt, District Plant Superintendent, Mountain States Co.; H. W. Kline, Division Superintendent of Plant, Mountain States Co.

recollect with pride that they were a part of the organization when, twenty-five years ago, that new instrumentality of communication was dedicated to the Nation's service. It is principally to the more than 200,000 Bell System men and women who know only by hearsay of the building of the First Transcontinental, therefore, that the following articles are addressed.

Two of them have been prepared especially for this issue of the QUARTERLY; the third was delivered by Dr. Jewett as the Steinmetz Memorial Lecture before the Schenectady Section of the A. I. E. E. on November 2 under the title of "The Technical Significance of the First Transcontinental Telephone Line," and has been edited only so much as is necessary to prepare it for publication. Read in sequence, these three articles must convey a clear sense of the great contrast between the telephone art of the present and of twenty-five years ago.

In the implications of that contrast the men and women of the Bell System will take a special satisfaction; for there they will find new testimony to the traditional policy of the organization that each great accomplishment—and the first bridging of the country by voice was that—shall be but a stepping-stone to further progress in the service of the public.

I. THE LINE AND THE LABORATORY

Research Was Called Upon to Provide New Knowledge, New Equipment, New Techniques, Before Construction Could Be Undertaken to Close the Gap in the Westward Wires

By JOHN MILLS

In the history of telephony, a crucial date is the year 1911, when service was opened between New York and Denver. The geographical range had stretched from the two miles of Boston–Cambridgeport transmission in 1876, past the nine hundred represented by New York–Chicago in 1892, to the twenty-one hundred of New York–Denver service. The first war with attenuation was over; but it had ended in a drawn battle, for the engineers could not have advanced farther without new weapons.

Those extensions of telephonic range were each the result of engineering developments and inventions. In that regard they were unlike extensions of railroad lines, which can be accomplished through sufficient capital, labor, and determination. It was not enough to build longer lines: it was necessary to talk over longer stretches of wire. The Denver line utilized every technique and refinement of telephone engineering of its day. Practically, it represented the limit of distance for telephone communication.

The reason that a telephone line cannot be indefinitely extended, like a railroad line, lies in the fact that a railroad train carries its own fuel and develops *en route* the energy for its own travel, while the trains of electric waves which carry telephone messages start out with the energy given to them by the transmitter and when that is used up they are powerless to move farther. Just as a railroad train in its travel must overcome friction, so a telephone train of electric waves meets frictional resistance as it progresses along the line.

Along the route to Denver, the wave train would lose one-tenth of its initial energy in traversing the first sixty miles of line. The nine-tenths of the original energy available at the end of that stretch would suffer a corresponding percentage loss while traveling the next sixty miles. The speech wave-train was decimated every sixty miles by the attenuating effect of the line. What reached the receiver at the end of a long line was, therefore, only a small fraction of what started.

To start much more energy was impracticable, as was the use of a re-

ceiver which, through greater sensitivity, would respond to much smaller currents, because a certain minimum of received current was required to stand out above any small extraneous currents which might be induced in the line by currents in any neighboring lines along its route. The received current had also to be sufficient to reproduce speech loudly enough to be heard above the ordinary noise of home, or office, wherever the receiver was located. The solution did not lie in the terminal apparatus; it had to be found along the line itself.

Along the line, rather than in the line. In the construction and equipment of the Denver line, about all had been done which could be done to reduce the attenuation, or weakening, to which telephone currents would be subjected. The line was built of 8-gauge (B.w.g.) copper wire, weighing 870 pounds a loop mile. This was because large wires carry electricity with less frictional resistance than do small wires. There is analogy with pipes carrying fluids. The size of wire utilized was as large as engineering considerations and economics would admit.

The Role of the Loading Coil in Long Circuits

ALONG the route, every eight miles, there was inserted in the line a large coil of wire with a magnetic core. These "loading coils," as they were called, although they did increase the length of wire through which the current had to pass *en route* to its terminal, served to make the line as a whole less highly attenuating than it would have been without them.

To fall for a moment into the phraseology of the electrical engineer, their presence increased the inductance of the line and thus offset, to a considerable degree, the effect of the capacitance of the line. Without defining these terms, it is enough to say that as a wave train travels along a line it encounters their effects, as well as that of electrical resistance. The amount of each depends upon the geometrical relationship of size of wires and separation between them. The percentage loss of energy which the wave suffers in each mile of travel depends in a complicated manner upon the magnitude of these three constants of the line structure, that is upon its resistance, capacitance and inductance per mile.

Capacitance is always present in a telephone line, but inductance may be negligible, as it is in cable, where the wires of a pair are close together. Since inductance and capacitance counteract each other to some extent, the absence of inductance in a cable circuit means that its capacitance is completely unmitigated. In open wire circuits, where the separation between the wires is usually twelve inches, the condition is much more favorable to transmission. The attenuation is correspondingly less, for the same size of conductor, but not as small as it would be if the inductance were large enough to offset the effect of capacitance.

That fact had long been recognized, but it didn't help the telephone engineer much, because he had no convenient way of increasing the inductance of a given telephone line. What he would have liked would have been insulated wires in a medium

AIR GAP LOADING COILS

Developed for the first transcontinental line. The large coil is for loading the phantom circuit, the small coils for loading the side circuits

more magnetic than free air, for then the inductance would have been markedly greater. That was difficult of accomplishment, although years later it became practicable with the development of permalloy, when in a submarine cable the inductance of the circuit was increased by wrapping the conductor with a thin tape of that magnetic alloy.

An obvious way of increasing the inductance of a telephone line, with the hope of gaining reduced attenuation, was to connect coils of wire—wire has more inductance coiled than straight—into the line every so often. If the coils had cores of iron, their inductance would be still higher. That was tried at times, but failed lamentably. The reason we now know to have been lack of knowledge as to the correct spatial separation of the coils along the line.

Some idea of all this had been adumbrated in the mathematical papers of Oliver Heaviside, an English genius whose expositions were not always easy reading. What was needed was a practicable engineering formula which could be applied to the construction of a telephone line.

THIS problem was attacked by more than one engineer, and two arrived at satisfactory solutions. One was Michael I. Pupin, who, about 1900, showed that the desired effect could be obtained if the coils were inserted at certain regular intervals along the line. The other scientist who solved the problem was George A. Campbell, a member of the technical staff of the American Bell Telephone Company in Boston. What these two men made independently was a basic invention for telephone lines, just as Bell had earlier made the basic invention for the terminal apparatus of telephony. To which of them, however, belonged the patent was only to be decided by a long court struggle, won by Professor Pupin, who sold rights to the American Bell Telephone Company.

MECHANICAL REPEATER, 1906
Early Shreeve Type

After this invention there remained to be solved many problems in the design and construction of loading coils, many researches to be conducted, and further invention. In this continuing work the practical formulae of Dr. Campbell proved most important. When properly designed loading coils were spaced approximately eight miles apart along an open-wire telephone line, its transmission efficiency was just about doubled. The effect of attenuation was halved and there was possible the same grade of telephonic transmission as in a non-loaded line half as long. That was about as much gain as could well be expected from loading, but it made telephony possible over the New York-Denver stretch.

Loading, besides presenting innumerable problems of its own, introduced others which required expert attention. One of these was the insulation of the line wires on their poles. New types of insulators and new procedures had to be developed, because in effect a loaded line worked at a higher voltage than did a non-loaded line, and there was a greater tendency for current to leak from the wires to the ground, particularly on rainy days. The problem took an acute form some years later when the line was extended west from Denver past Great Salt Lake. There, the windblown salt spray had a serious effect on insulation, and considerable special engineering work and maintenance was required in that section of the transcontinental line.

The Development of the Mechanical Repeater

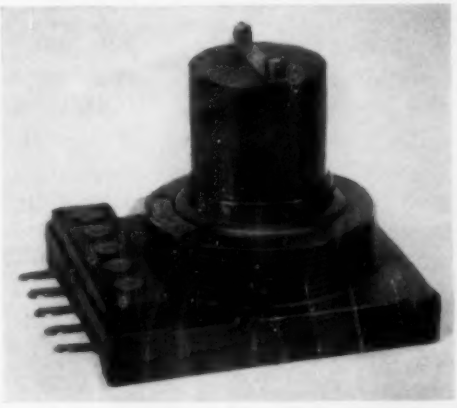
WITH the introduction of loading and the development of coils excellent from the standpoint of that day—although not so small, efficient, and inexpensive as those of today—the engineers had done about all they could to the line itself to increase the range of telephony. Any advance, it was then obvious, must come from developments along the line. In that regard there was an analogy between telephony and the earlier art of telegraphy. The coded signals of telegraphy, initiated by a key which connected a battery to the line, and interpreted by a sounder at the receiving end, were also limited in the distance they could effectively travel. To extend their range, so-called telegraph repeaters had been developed. These were relatively simple devices in which the moving member of the sounder, instead of merely clacking against a stop, was arranged to operate a switch, connecting a battery to the next section of line and, consequently, sending along that line a new signal similar to that which was received.

Much effort had been spent upon the development of a telephone repeater which would receive the telephone current from a distant trans-

mitter and initiate, in another transmitter, a replica of that current to travel on to a more distant receiver. The problem was fraught with difficulties, because the telephone current was much more complicated than the telegraph current and involved a much wider range of vibration frequencies.

Many attempts were made to combine receiver and transmitter into a telephone repeater. With one exception these were essentially fruitless. The exception was a mechanical repeater invented by Herbert E. Shreeve of the American Bell Telephone Company and later of the Engineering Department of the Western Electric Company. This device had a fairly successful test in 1904 on a telephone circuit between Amesbury, Massachusetts, and Boston, where its introduction resulted in greater intelligibility in the transmission than could be obtained over the line without the repeater.

THE device went through a number of forms in the hands of Shreeve, R. L. Jones, and their associates; and it served with considerable success in certain situations. Inherently, however, it had a number of defects. One was its disproportionately smaller sensitiveness when the incoming telephone current was very small. For that reason, although it might work in a telephone line over which two persons were speaking loudly, it might be almost useless in a long line when the speakers had weak voices. Its chief defect, however, was a lack of fidelity in recreating the telephone current: it had a tendency to favor some pitches, or tones, of voice and



MECHANICAL REPEATER, 1912

Final cartridge type

to discriminate against others. That, added to its tendency to give greater amplification to the stronger tone, meant a certain inexactness in its copy of the telephone current. The effect was not so bad if only one repeater was in the line between the parties conversing; but on a long line, where several repeaters in succession had to be installed, speech might be distorted into unintelligibility.

Each successive model of the device, however, showed distinct improvement over its predecessor, and, in time, particularly with the application of more modern knowledge as to mechanical vibrating systems, it would have served more widely, had not other types of repeaters been developed.

Aside from the defects which it had, it was charged with incapabilities for which it was not itself to blame. It failed almost completely when connected into loaded lines. The difficulty arose in part from expecting the repeater to adapt itself to the line, when what was required was some

adaptation on the part of the line to the use of repeaters. The necessary techniques were developed later in connection with the first transcontinental line. As a matter of fact, the Shreeve repeater was successfully used in commercial service for a few days in 1915 over the transcontinental line, in which it had been installed for that purpose at Pittsburgh, Omaha, and Salt Lake City.

Organizing the Research for a Practical Repeater

THAT New York–Denver would be the practical limit of distance for telephony unless the problem of telephone repeaters could be satisfactorily solved was recognized several years before that line was ready for service. Concentrated attention to the problem was proposed by J. J. Carty, then Chief Engineer of the American Telephone and Telegraph Company, and approved by its then president, Theodore N. Vail. Carty asked for more men and dollars to apply to the project of the development, by further research, of a telephone repeater suitable to operation on long loaded lines. It is interesting to note, however, that his memorandum on this subject went further and pointed out that the problem of long distance radio telephony might also expect solution as a result of the development of a satisfactory telephone repeater.

Starting in the winter of 1910–11, a small group of scientists was selected and research initiated under the general guidance of Dr. F. B. Jewett, who was then Transmission and Protection Engineer of the American Telephone and Telegraph Company. The men who were to investigate the problems which loaded lines presented to repeaters were in Dr. Jewett's department in the telephone company; those who were to make a laboratory attack on the repeater itself were grouped into a research department under Dr. E. H. Colpitts in the Engineering Department of the Western Electric Company. The scientists thus assembled became the nucleus of the present Research Department of Bell Telephone Laboratories. A year later Jewett became Assistant Chief Engineer of the Western Electric Company, and in that position coördinated the entire transcontinental line research, whether carried out in the laboratory or in the field.

THERE was a third phase to the repeater problem. It was not enough that lines should be adapted to repeaters and that repeaters should be developed which would be effective and distortionless in their operation; there were also necessary suitable circuit arrangements for the introduction of repeaters into the lines. This was well recognized by all those concerned and was a project to which both groups contributed.

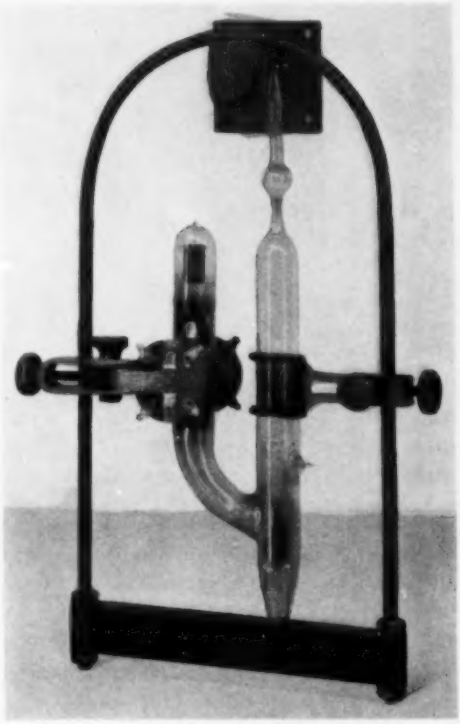
The difficulties of the mechanical type of repeater were due in part to inertia, which is inherent in any mechanical device. The diaphragm of its receiver portion had to vibrate at any and all the frequencies involved in the speech wave and at the same time drive at the same vibration rates the movable electrode of the carbon button transmitter. The inertia effects were recognized by Jewett and

his associates, who looked for moving parts of lighter weight. Instead of vibrating diaphragms they considered the possibility of electrified molecules of gas or even of free electrons—the tiny parts of atoms which science had recently recognized.

FIRST among the scientists enlisted in the research group was the late Dr. H. D. Arnold, who had had his training under Professor R. A. Millikan at the University of Chicago and was most highly recommended by him. Arnold first turned his attention to the development of a repeater which would utilize gas molecules.

He set up a tube in which there was an electrical discharge current carried by a stream of electrified—that is, ionized—molecules of mercury vapor. Then he arranged to wobble that stream sidewise through the magnetic action of a telephone current in a coil essentially similar to that of a telephone receiver. In the tube he placed two metal plates or electrodes. To these he connected a battery and a transformer in such a way as to form a transmitter the movable constituents of which were ionized molecules of gas instead of carbon grains. If there was no current in the receiver coil, then the arc stream flowed steadily and was undeflected, and there was no current from the transmitter. When the arc stream was vibrated by an incoming telephone current, there was produced an outgoing current of similar vibrations, but of a magnitude greatly increased because of the power available in the battery.

That ingenious mercury-arc repeater was capable of good amplification, but it had a serious tendency to

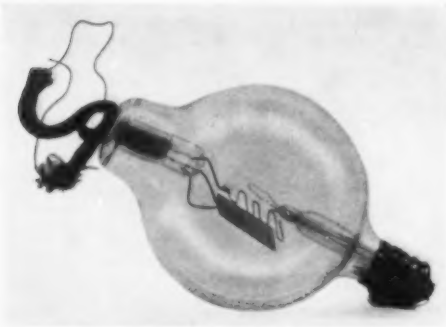


MERCURY ARC REPEATER TUBE, 1912

The development of the late H. D. Arnold

be noisy in a way somewhat similar to that of an old-style carbon transmitter when it "burned" and "sizzled." It was tried out experimentally on telephone lines, but it was used only under special engineering supervision, and never for any length of time. Development work on it was dropped early because of the much greater promise of another device.

This was the audion of Dr. Lee DeForest, one of the most interesting and important inventions in modern electrical arts. Although at that time a very crude instrument, incapable of being used immediately as a repeater in the telephone plant, its possibilities



DEFOREST DETECTOR, 1908
Side view of the single plate audion

were recognized by Jewett, Colpitts, and Arnold, and a program of research was undertaken, directed towards its development and application as a telephone amplifier.

The Genesis of the Vacuum Tube Repeater

IN its grosser elements the 1908 audion of DeForest is the vacuum tube of today, utilized in millions of radio receivers, in hundreds of thousands in the telephone plant and in thousands by the motion picture industry. From a device capable of handling only a watt or less, it has been developed into forms capable of controlling a hundred or more kilowatts. When the audion was invented, the electron which is its active agent was practically unknown; and its development into the versatile vacuum tube of today followed, but also contributed importantly to, the modern physics of electronics.

The audion was a small glass bulb, evacuated according to the manufacturing techniques of its day. To its partial vacuum the electrical entrance was through four sealed-in wires. Between two of these was a lamp filament which could be heated to a bright red by connection to a battery. The third wire ended in a metal plate parallel to the inverted V-shaped filament. The fourth connected to a grid of wires located between filament and plate.

The action is to be described in terms of electrons. The current which heats the filament is a pellmell stream of electrons, and some of them get going so fast as to break completely away from the filament and issue into the surrounding space. Technically speaking, there is a thermionic emission of electrons. Within the evacuated tube there is, therefore, an atmosphere of electrons; in their motion some will find their way back to the filament, strike into it and take up their former activities as current carriers. For any definite temperature of filament a state of equilibrium is quickly attained with about as many returning each moment as leave the filament.

When the plate is made positive with reference to the filament, by connecting a battery between them, the equilibrium is upset and the electron atmosphere is drawn toward the plate. There is then a stream of electrons from filament to plate and back to filament through the wires of the battery circuit. If the battery is reversed, the plate repels electrons and there is no current in the filament-plate circuit.

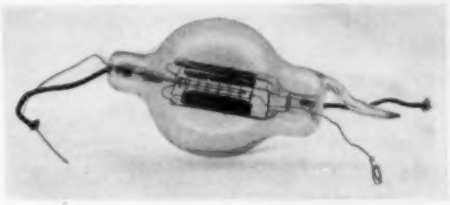
That one-way conductivity of the filament-plate circuit of a vacuum tube had been recognized, but not applied, by Edison years before DeForest. It had been applied by Fleming, an English radio experimenter, in a radio detector. To the high-fre-

quency currents of a receiving radio antenna the filament-plate circuit would offer conduction for alternate halves of the waves only, acting like a valve and rectifying the alternating current so that its signal-bearing variations could be heard in a telephone receiver.

DeForest's contribution was the wire grid which allowed another current path through the tube: a path from filament to grid, which is of tremendous value because the strategically-placed grid can exert a sensitive control on the electron stream in the plate circuit. As DeForest used his three-element tube, the alternating electromotive force derived from a receiving antenna was applied between grid and filament. A telephone receiver and battery were connected between plate and filament. When modulated radio waves were received, the current in the receiver varied in correspondence with the speech or telegraph modulation.

SUCH was the audion which the agents of DeForest offered to the American Telephone and Telegraph Company in 1912. It was suggested that it could serve as an amplifying element in a repeater circuit. An incoming speech current was to be fed into its grid-filament path and an output current obtained from its plate-filament circuit, using a local battery as a source of energy. (Another battery heated the filament.)

The audion was tested, and it was found that under laboratory conditions it could amplify weak telephone currents supplied to it over quiet artificial lines. Actual lines, however, are inevitably noisy—that is, carry some



EARLY HIGH-VACUUM REPEATER

First type, used at Philadelphia in commercial telephone service, 1913; made by Western Electric Company

extraneous currents—and speech currents must never be allowed to fall too low, lest they be obscured by noise currents. Telephone currents, although themselves small, are on the average much larger than the very feeble radio currents with which the audion had previously dealt. And it was found that when the audion was called upon to handle the typical value of current which might be expected at a telephone repeater station it would fill with blue haze, seem to choke, and then transmit no further speech until the incoming current had been greatly reduced.

The explanation came from the researches of Arnold, to whom in the meantime the device had been turned over for investigation. Arnold recognized instantly its inherent possibilities and the cause of its incapacities. Instead of looking at it as did radio engineers, to whom it had been for years a familiar device, he considered it as a specific instance of the general problem of conduction of electricity through vacua. The control which the grid exerted on the current between filament and plate was effective only when the electromotive force it applied was relatively small. When too large, the stream got out

of control and increased without regard to the electrical status of the grid; a blue haze then filled the tube.

Arnold recognized at once, because of his basic knowledge of the infant science of electronics, that when the stream was controllable, it was a stream of electrons; but when it disallowed the authority of the grid, it was because ionized molecules of gas were taking part in the performance. To permit stability of operation and accurate control, the current through the tube must comprise only electrons. The audion, as was, contained too much gas—mostly plain air. A higher vacuum was necessary, and one of his tasks was to apply and to extend the latest techniques for producing high vacua.

THE blue haze occurred if gaseous molecules were present in too great density and if the electromotive force applied—the combined force of the battery in the plate circuit and the e.m.f. (electromotive force) in the grid circuit—was large enough to give the electrons, in their travel toward the plate, speeds high enough to do real injury to the gas molecules with which they collided. In such a case an electron impact will dislodge one of the electrons of a gas molecule, and two electrons will then have freedom where only one had it before. The original electron will continue its journey toward the plate, and the one it has manumitted will also start off in the same direction. Both may pick up speeds to do further damage, and the current is thus automatically increased by these "ionizing" collisions.

The blue haze which is the evidence of such spontaneous ionization is accounted for by recombinations, in collision, of electrons and ionized atoms—that is, those which have lost electrons and are therefore electrically compelled to move counter to the electron stream. Improving the vacuum decreased the chance of collisions, whether of ionization or of recombination, and ensured that the filament-plate stream should be purely electronic.

When it is electronic its strength, other things being equal, is delicately determined by the e.m.f. impressed on the grid circuit. The grid is strategically placed much closer to the filament than is the plate. A small change in the e.m.f. applied to the grid produces, therefore, as much effect as would one several times as large applied to the plate. How much more effective a fraction of a volt may be, in altering the intensity of the electron stream, when applied to the grid instead of the plate, is a matter largely of the spatial arrangements of the three electrodes within the tube. Those relationships Arnold studied; and on their basis he redesigned the audion to make the first three-electrode high-vacuum thermionic tube. That tube became the amplifying element of the telephone repeaters in the first transcontinental line.

Incidentally, Arnold and his associates, who included O. E. Buckley, H. J. van der Bijl, and W. Wilson, also constructed a year later much larger and more powerful tubes—tubes in which the grid could control an electron stream of more power. Using them, the Bell System inaugu-

rated its program of radio development, the first epoch of which was the transatlantic transmission in 1915 of a few words from Arlington, Virginia, to Paris. That, however, is another story.

So also is the patent litigation which arose around this development of a high-vacuum audion. At the time Arnold, himself, did not feel that his decisive improvement in vacuum of the DeForest audion constituted an invention. It was some time later, when it was learned that a scientist in another industrial laboratory, Dr. Irving Langmuir of the General Electric Company, had applied for a patent on that score, that the contest began. It was carried through all the possible authorities, from patent examiners to the United States Supreme Court. This final authority decided that invention was not involved; but it added in its decision the statement that, if it had been, the invention would have been Arnold's.

The audion was invented. The vacuum tube was developed by methods of pure science which were brought to its study in the spirit of research.

The Problem of Loading Coils in Circuit with Repeaters

WHILE these promising developments had been under way in the laboratory under Dr. Colpitts' general oversight, other members of Dr. Jewett's force had concentrated on the very serious problems presented by loaded telephone lines. Experience with the mechanical repeater on loaded lines had shown that little amplification—too little to be practical—could be obtained by its introduction on such lines. If a repeater was adjusted to give more than a minimum of transmission gain, it sang—or, more accurately, it howled with discordant screeching.

The reason was inherent in the reciprocal nature of conversation and in the corresponding utilization of a single pair of wires as a medium for two-way transmission. A repeater, near the middle of a line, was expected to react to speech current from either direction and to send out instantly an amplified reproduction of that current. Since the repeater was incapable of determining from which direction the speech was coming, its transmitter attempted to distribute amplified current impartially in both directions.

If it could do so, all was well; but if it could not, its receiver got more current from one direction than from the other. To the excess which it received it responded exactly as to a speech current from a distant terminal. Its output was an amplified version of that input. But that output, in turn, failed to divide equally, and supplied a further excess to the receiver. The process was cumulative, and the repeater was soon buzzing along on its own, without regard to whether there was any conversation or not. The current it sent out was that of a tone determined by its electrical or mechanical preferences as to vibration rates: in other words, it "sang" at its own natural frequency.

The more efficient the repeater was, that is, the greater the ratio of the current it emitted to that which it had received, the more it would tend to sing, for any situation in which it was placed. Of course, if it didn't am-

plify at all there was no possibility of singing, so that one cure was to decrease its efficiency as an amplifier.

The other way was to use the repeater in situations where it was easier for it to avoid singing because its output current divided more evenly between the lines on either side of itself. Ordinary non-loaded lines, particularly if they were very long on either side of the repeater station so that any difference in their terminal conditions was minimized, were rather favorable to repeater operation; but the trouble was that when they were favorable they might be so long that the repeater heard so little it was licked to start with. For the repeater to be useful, the lines on either side of it had to offer approximately similar absorption for its output current —that is, technically, have equal impedances. The more nearly similar the lines, the greater the amplification which the repeater could give, as G. A. Campbell showed precisely by a mathematical analysis made during the early days of the transcontinental line project.

THAT loaded lines were unsuited to repeater operation had been proved by experience. Scores of loaded circuits in the New York–Philadelphia cable had been measured by R. S. Hoyt both ways from their midpoint at Penn's Neck. In each case he had measured their impedances to currents at a large enough number of different frequencies, in the range they could transmit, to get a complete picture of their impedance-frequency characteristics. And no two of them looked anywhere near alike. Since the transcontinental line would have to be formed by open wire, Hoyt and John Mills were given the task of investigating loaded open-wire lines and, if possible, of learning how to adapt them to repeater operation. Besides Hoyt's experience, they had the advantage of frequent consultations with two senior members of the Transmission Department, Otto B. Blackwell and C. A. Robinson.

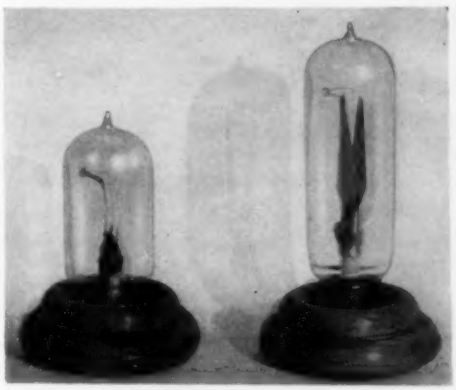
Their work centered on Morrell Park, the open-wire terminal at Chicago, where there was available the largest number of loaded lines. Again the tests showed no two lines with suitably equal impedances. When they brought their curve-plotted data back to New York, after measuring all the available lines, there was one curve which fascinated Mills, who was a complete novice at telephone transmission just recruited from college teaching and shipped to the field for nights of testing with hardly an idea of how a long-distance telephone line looked anyway. The graph was a wavy curve with several large ups and downs, recurring almost regularly as the frequency of the test current was increased.

IT was such a satisfying picture of regularity, as compared to the more-than-stock-market-graph irregularities of all the rest, that he persisted in drawing attention to it and urging its study. Calling it to Hoyt's attention one day, by its route and pair number, he was overheard by Robinson, who immediately asked if the "office loading coil had been in circuit." An intermediate office on that route came practically at a loading point; and when the line was used for through service, rather than terminating, the

coil was supposed to be cut in. Blackwell, in turn overhearing this question—for all four, along with H. S. Osborne, shared a common office—brought his theoretical background to the problem. Curves were laboriously calculated for a hypothetical line, with and without a missing coil at that given distance away; the regularity of the wave-shaped graph was unmistakeably due to the loading irregularity of a missing coil. A formula was obtained for estimating distances to loading irregularities, and Hoyt and Mills went back to their tests to see how smooth and similar they could make the impedance-frequency characteristics of loaded lines.

To get convenient quantitative relationships between loading irregularities and impedance irregularities, they also set up a long loaded artificial cable in the Research Laboratory at 463 West Street. With this they obtained whole families of graphs covering all sorts of carefully controlled conditions, including single and multiple irregularities. (Incidentally, all the measurements used as a current source the Vreeland oscillator, a mercury arc device which served excellently in the audio-frequency range before the vacuum-tube oscillator was developed; and it is here tardily given the hand it deserves). These measurements were soon to pay excellent dividends; but in the meantime the work had struck a snag.

A particular open-wire loaded line did not always have the same characteristic two nights in succession. Plant reports showed no trouble from lightning; no coils had been strapped out; and yet the line showed a different—and always unanalysable—



FLEMING VALVES
Two-element tubes used in wireless before the audion

mess of small loading irregularities. Large ones, of course, were easily located and corrected. Through the further coöperation of the Long Lines Department, whose wire plant out of Morrell Park was already a widespread laboratory, Mills was allowed to undertake a periodic examination of individual loading coils on the Newtown Square–Pittsburgh lead. The coils were connected by Fahnstock clips so they could be disconnected from the line wires and attached to portable measuring equipment which determined their inductance.

ALL one summer a group of young men, assisting W. N. Rorer, rode that line, each man measuring the coils along his section and retracing his path to test them again. Only rarely did two successive measurements on different days agree. The inductance of a coil varied as much sometimes as it would under laboratory conditions if shot with two or three amperes of direct current. It was al-

most inconceivable that the high-voltage lightning could produce an equivalent effect without wrecking the coil. There was no discernible effect of lightning; and a coil which one day was seriously low in its inductance might be back almost to its nominal value on a succeeding day. But there was no other cause to assign. And proof of it came when Osborne, who was in California on other work, tested the coils along a lightning-free route and reported all of them within factory limits of their nominal values.

That put the problem squarely up to the coil designers, and T. Shaw, downtown,* and W. Fondiller with his associates, uptown,† went to work. Greater magnetic stability was required in the iron cores of loading coils. Air cores were proposed for a time but, in default of the present day methods of iron dust cores to which this work was preliminary, a proximate solution was found in segmented cores with intervening air gaps. New coils had to be designed on that basis, tested for approval, pots designed to hold them, and manufacturing methods established. In that work many men were creatively concerned whose numerous identities are passed over and inadequately credited by the brief statement that the Physical Laboratory and the Manufacturing Department of the Western Electric Company did the job in their usual competent manner.

For its day, what the coil designers promised was a remarkably efficient and stable coil. It underwent tests which showed it would stand up in the field, maintaining values within reasonably narrow limits of its manufactured condition. But there was still a range of values which any coil might have, rather than some single very definite value, and hence as many sources of irregularity along a line as there were coils en route. Assuming this range of irregularity, and utilizing the experimental data on the effect of multiple irregularities which had been carefully collated by Hoyt, Mills made a probability study of the irregularities in line impedance which might be expected from a multiplicity of small irregularities in coil inductance and in coil spacing—for the spacing on many existing lines was only approximately regular. In grinding the mathematical crank that transformed his premises into conclusions, he had the very necessary assistance of E. C. Molina, the pioneer probability expert of the Bell System. The conclusions did not indicate as happy a probable state of affairs as could be wished.

IN a memorandum, to be published years later in his collected works, Campbell had analyzed the telephone repeater circuit and had related possible repeater gain to the impedance differences between the lines on either side of it. Combining the results of that analysis with the existing small amount of data as to gains obtained with mechanical repeaters on lines of more or less accurately known impedances, Mills had obtained a cruder empirical relation which specified in the units of that day—which knew not the euphonious decibel—the possible repeater gain for any given per-

* A. T. & T. Co., 195 Broadway.

† Western Electric Co. Engineering Dept., 463 West St.

centage difference between the impedance-frequency characteristics of its associated lines.

That formula, combined with the probability study, showed too small a chance—even with the proposed new coils and with spacing accurate to half an ordinary pole span. The little irregularities might add up to too large a total effect. But there was a saving possibility emphasized in Campbell's memorandum. The circuit hitherto employed used one amplifying element and sent its current two ways. It was a two-way one-element repeater—a 21-type repeater, to use the terminology later adopted. Campbell pointed out the advantages of the previously known but not used 22-type repeater *; one in which two similar repeater circuits were used and two artificial lines. The lines which entered a repeater station, in that scheme, were not to be connected together by a repeater circuit. Instead, each line was joined by a repeater circuit to a dummy line; then the transmitters of the two amplifying elements were crisscrossed in connection so that each element fed its outgoing current to the line and the artificial line which were associated with the other repeater circuit.

The Balancing Network Proves to be the Solution

IN this circuit it didn't make any difference how unlike in impedance were the two lengths of actual line; what was important was how closely each line was simulated in impedance by the artificial line which balanced it. If each of the lines on the two sides of a station were perfectly balanced by dummies (or networks), even though the two lines were of unequal impedance, any current transmitted through the repeater in one direction would divide with perfect equality between the line and its network, with the result that no current could flow back through the repeater in the other direction. Of course, perfect balance is impossible; nevertheless, this two-way two-element circuit provided the margin necessary to make transcontinental telephony possible. The trouble was that a loaded artificial line would be bulky,

VACUUM TUBE REPEATER, 1914

This was the vacuum tube repeater element used in the test conversations between New York and San Francisco

* Invented by W. L. Richards of the American Bell Telephone Company.

very expensive to build, and two would be required at each repeater station.

Telling Hoyt his pessimistic conviction, Mills stated his conclusion that the only solution was to use the 22-type circuit, and he asked Hoyt's opinion on the feasibility of some suitable dummy line. Hoyt got out the family of curves on loaded circuits and almost immediately announced that a simple network could be made to simulate a loaded line if it terminated at a particular point in a loading section. Building out that network to any other fraction of a section was equally simple.

With Hoyt's invention of the first balancing network for a loaded line, the problem of adapting such lines to repeater operations was as good as solved; all that remained was plenty of hard work for all concerned, and some occasional ingenuity, in adapting old lines or building new ones. At the Laboratories, B. W. Kendall, R. C. Mathes, and W. L. Casper set to work on engineering the 22-type circuit with its necessary transformers; Hoyt devoted himself to network design; Arnold made improved vacuum tubes, using a filament constructed by A. M. Nicolson which was extremely efficient in emitting electrons; Mills with several associates tested and adapted lines; Robinson and A. B. Clark worried over the insulation problems at Great Salt Lake; and everybody was more than busy.

Summarizing the progress which had been made, Jewett could assure Carty that the project would be completed. A desired date had already been set by Carty and a condition added which, while very severe, introduced some amusing interludes. Carty insisted that no through test should be made on the line and that Vail should say the first words which traversed its entire length.

As a testing ground for all the new repeaters—the latest model of the mechanical, the mercury-arc, and the redesigned high-vacuum form of the audion—Philadelphia was chosen, because of the loaded circuits available in the New York–Washington cable. Shreeve and Mills, with the coöperation which they had learned to expect from the Long Lines Department, rented a room in the Bourse Building and ran leads to the test board on the floor above. And in that room Colpitts, Arnold, Kendall, E. O. Scriven, W. N. Thompson and others of the group worked many nights studying repeater operation on circuits withdrawn temporarily for that purpose from commercial service.

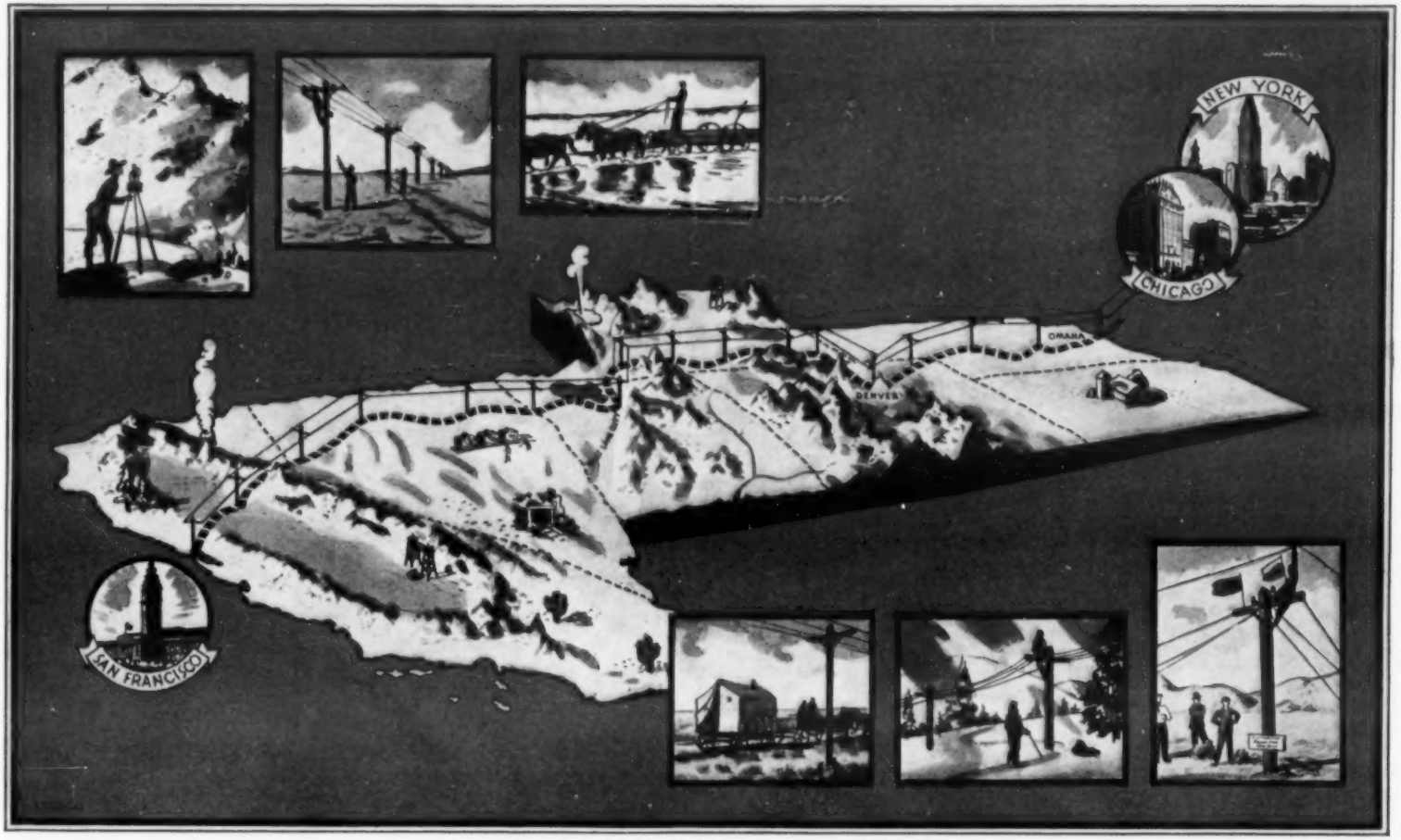
During March of 1914, when a severe storm took out many lines from Washington south, Shreeve's prompt action put this repeater room to good use. When early reports of the storm's extent began to reach New York, he sensed the situation and knew that without repeaters at Philadelphia the underground cable couldn't replace the long-haul open-wire circuits. So he telephoned Jewett, caught the next train, opened up the room, and put five repeatered circuits into the Plant Department's emergency service.

In the meantime, the Long Lines Department and the Pacific Telephone and Telegraph Company were solving their construction problems,

installing at very regular intervals the huge pots containing three loading coils—two for side circuits and one for the phantom of the four wires—placing an improved design of insulators, and building a world-famous telephone line. At Pittsburgh, Chicago, Omaha, Denver, Salt Lake City, and the previously little-known town of Winnemucca, Nevada, special test rooms were set up and vacuum tube and mechanical repeaters installed. This work all went on under the personal supervision of Colpitts, who was usually to be found at the point where the need was most pressing. Shreeve and Kendall, installing repeaters, and Mills, clearing lines, with Colpitts not only as boss but sometimes as mediator between the claims, or claimed defects, of lines and repeater circuits, sweated west during the late spring and early summer of 1914.

BECAUSE of a proposed absence of Vail in the late summer, Carty had advanced the date on which he wanted the first through conversation for engineering tests; and July 29th was the goal. In the repeater room at Salt Lake City a switch had been put in the line, and definite orders were given to O. A. Pawlick that it should not be closed until time came for Vail's conversation with President G. E. McFarland of the Pacific Telephone and Telegraph Company at San Francisco. To officiate at the time, Shreeve had been sent to San Francisco. When the time came, he had a short circuit across the transmitter at which McFarland sat; and not until he had heard Vail's voice in his monitoring receiver did he cut it with the pliers he had provided for that purpose. Like an unveiling ceremony, when the cords are drawn or cut, the line opened to the telephone executives on opposite sides of the continent.

THAT is the technical history of the first transcontinental line as one man saw it and remembers it. Obviously an incomplete story, it offers its apologies for omissions of names and accomplishments. Only an article many times longer could do justice to that development, and for that the existing records are too meager. Documentary research would not yield its complete story. Much of it would have to come from the memories of Jewett and of Colpitts. Arnold, the third of those most responsible for the achievement, is dead; but his technical contributions have left a profound and continuing effect on all the communication arts.



WESTWARD THE COURSE OF SERVICE

The third dimension of this sketch-map gives some conception of the terrain across which the first transcontinental telephone line was built as it reached out from Denver to the Coast

The third dimension of this sketch-map gives some conception of the terrain across which the first transcontinental telephone line was built as it reached out from Denver to the Coast

II. THE CIRCUITS GO UP

Construction Completed Despite Nature's Obstacles, Impressive Ceremonies Gave Notice to the World that the First Telephone Line from Coast to Coast Was a Working Success

By H. H. NANCE and R. M. ORAM

The building of the first transcontinental telephone line was not a single project in the same sense as was the Panama Canal. While there had been a steady progression of the country's telephone system westward from the Atlantic shore, it had been a succession of steps, each attaining to a definite goal, and each linking the telephone's newest frontier with the East. Moreover, each step represented about the maximum extension which was practicable at that stage of the art of telephony.

We can be fairly certain that the idea of coast-to-coast service was in the minds of telephone men for many years. For one thing, we can go back to the American Telephone and Telegraph Company's charter, issued in 1885, and find the incorporators talking about service to "each and every other of the United States, and . . . the rest of the known world." And when J. J. Carty, then A. T. & T. Chief Engineer, visited San Francisco with F. B. Jewett and Bancroft Gherardi in 1908, the subject of telephone service to the East was discussed at length with municipal officials and business leaders there. Again, Carty's biographer relates that, while in a West Coast city, Carty saw a statue to Seward, Lincoln's Secretary of State, on which was the inscription "To a United Country"—which evoked the remark that such a thing could not be considered a reality until the country was united by telephone. There are many such incidents in telephone history reflecting the idea of *universal service* which marked the leadership of Theodore N. Vail, who was President of the American Telephone and Telegraph Company.

So we know that the hope, the aim, the expectation of talking from coast to coast had been crystallizing even before telephone wires crossed the Mississippi. But when President Vail reached the decision that a transcontinental line should be built, there was little to indicate that, on the basis of immediate demands for transcontinental service, the undertaking would justify itself economically; or, for that matter, that in the existing state of the telephone art it could be carried through successfully. It was typical of his leadership that if a project was needed, its immediate practicality did not interest him;

it would prove its value—and it invariably did.

So, among the raw materials for this undertaking of closing the gap across the western section of the country was a great deal of faith; for at the time of Vail's decision, the vacuum tube repeater that was eventually used—and the only type of amplifier which made coast-to-coast telephony possible on a satisfactory basis—had not even emerged from the laboratory.

The Problems Were Many, Varied, and Great

THERE was something else that would make this last jump a real hurdle, and a formidable one to negotiate. In all of the previous westward extensions, the line had gone through territory that was developed to some extent. As it pressed onward with the years—to Chicago, to Omaha, to Denver—its every further stride brought to more people a quick and intimate contact with increasing areas of what was, to each newly reached territory, "back East."

But in those days there was little development, except at Salt Lake City, between Denver and the Coast. West of Denver it would be "San Francisco or bust!"

In still another way the problem was quite different from that of digging General Goethals' "Big Ditch." As the editor of a New York paper afterwards expressed it, it was "a struggle and triumph against microcosmic difficulties, a victory over tremendously important trifles, where the Panama Canal had been a titanic battle between the master-machines of man's devising and the might of Nature." The construction itself, building new pole line and stringing new wires, was an arduous task, but it presented no particularly new problems. The real problem was to make the wires talk satisfactorily across the face of a continent.

West of Denver the actual pole-line work consisted mainly in closing gaps in lines already built along the principal way of travel into California. This required the construction of a new pole line from a point just west of Salt Lake City across Utah and Nevada, a stretch of some 475 miles. A 96-mile cut-off was also to be built northwest of Denver, where the existing line made a long detour. In addition, considerable pole replacement work was required to strengthen the existing lines.

It having been decided that the transcontinental line should be ready for commercial service upon the opening of San Francisco's Panama-Pacific Exposition, early in 1915, construction work was begun by the Mountain States and the Pacific Telephone and Telegraph Companies in the Summer of 1913.

ONE of the first questions to settle was raised by the Great Salt Lake. The natural route for the telephone line followed the Western Pacific Railroad, south of the Lake. But there was a serious problem of insulation in this region to solve first. During damp weather, moisture settled on insulators which had become coated with salt dust blown there by the wind. This combination seriously impaired the insulation. Exhaustive tests showed that if the insulators were clean when they were first in-

MEASURING THE SPAN
The surveying party lays out the route in Nevada

stalled, and were thereafter cleaned periodically, they would hold up. In this section, therefore, every insulator was washed carefully with spring water—hauled, sometimes, from a spring sixty miles away. Thereafter, a specially developed mobile "vest pocket" boiler and steam jet were used for routine cleaning.

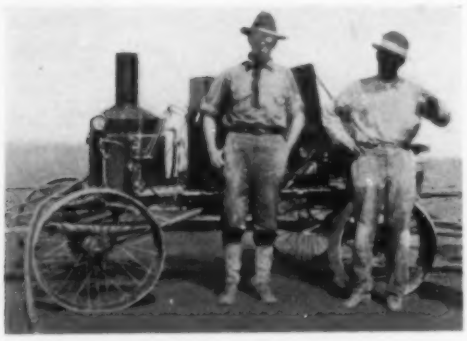
Once it became evident that these measures would be effective against the salt condition, it was decided to follow the shorter route south of the Lake.

It may be interesting to accompany the party that surveyed the route between Denver and the Nevada state line. It consisted of about a dozen men, and traveled usually in wagons drawn by horses or mules, with tents and full equipment, and food and supplies for many days. By arrangement with the railroad, their water was brought to a convenient siding in a tank car, and another car brought food and supplies at regular intervals. Sometimes a couple of box cars replaced tent and wagon as living quarters and means of transportation.

Built by Men of the Mountain States and Pacific Companies

THE procedure of the survey party was for the chief of the party to ride ahead—he was the only one on horseback—and trace out the general course to be followed. Traversing the 7,000-foot plateau north of Denver, the surveyors had no rugged heights to scale or skirt, but the ground was sufficiently irregular to make a survey without topographical maps—not then available—a laborious task.

The principal reference marks in work of this kind were the "cornerstones" marking the corners of mile-square sections into which that region had been divided by government surveyors. But these cornerstones were



TEAKETTLE ON WHEELS

This mobile boiler provided a steam jet for cleaning insulators on poles in the vicinity of Great Salt Lake

not always to be found, so that the task sometimes resembled that of a navigator off-shore.

The navigation was complicated at the outset by a rather unusual phenomenon. In the region north of Denver, the surveyors passed near a mountain in which were deposits having such marked magnetic properties that the compass was of little use, and they were obliged to fix their position from time to time by astronomical observations with their transits.

While the salt and mud flats west of Salt Lake City were no playground, that particular stretch presented no difficulty from the surveyor's point of view. It is on these salt flats that Ab Jenkins, Sir Malcolm Campbell, and others have in recent years hung up such astonishing automobile speed records. Level as a pool table, the expanse of salt and mud offered no topographic problems. It was merely a task of laying down a line of stakes parallel to the Western Pacific roadbed and 1,000 yards north of it, in a bee-line stretching from one horizon to the other for a distance of about 42 miles.

Following upon the heels of the survey party came the line gangs of the Mountain States Company. They traveled like the survey crew, with teams carrying tents and supplies, or in box cars. The foreman was known by the cook he kept, and he generally had a good one. Eating with the construction gang was a rite which many telephone engineers who travelled over the route remember with pleasure.

LIKE the surveyors, the construction men ploughed into some rough weather at the outset, and from the end of October onward, almost everybody was on snow-shoes, and the material was hauled on bobsleds. A foreman working near Leroy, Wyoming, tells of getting "no bottom at twelve" in a gulley, with a pike pole. With this came considerable subzero temperature, and there is a legend that in more than one case the men never knew how cold it really was, because the foreman took the thermometer to bed with him.

Out on the salt and mud flats, these gangs found entirely different conditions, equally arduous. This arid expanse, devoid of vegetation, is the bed of a prehistoric lake. In the winter there is a considerable amount of casual water, blown about the flats by the wind. When the wind is from the north there may be a foot or so of water on the route traversed by the telephone line. During the construction work, this phenomenon produced a certain amount of water-borne commerce, it being frequently necessary to haul materials from the railroad to the line on rafts.

The ground on these flats was mostly mud, and often caved in as the holes were dug; while in other places, when holes were blasted, the dynamite blew the salt away, leaving little to pack the poles with. But somehow rock or other material was found to pack the sides of the holes and give the poles a firm footing.

With the advent of summer, the temperature in this region sometimes went up to 130 degrees. The reflected glare from the sun was blinding, and even the horses wore dark spectacles.

MEANWHILE the men of the Pacific Company were encountering equally arduous and varied conditions in their work across Nevada and through the Sierras.

Over a considerable part of the route to be followed in Nevada there were no roads. As a first step the Company sent out a construction foreman who knew the country, to trace out the best path. Following him, the survey party was guided by the stakes he had driven and by wooden laths placed in prominent places—perhaps with a note with directions to nearby water-holes and other useful information.

After the survey party, the construction gangs had to do a lot of their own road-building—which at times included bridges.

Along this route, water was a frequent problem. Sometimes it was uncomfortably scarce, sometimes overabundant. For instance, there was Humboldt Sink, a lake of uncertain extent west of Lovelock, Nevada. The gang delivering supplies had laid poles, in piles of about twenty, near this body of water, along the line marked by the surveyors. It might be explained that the word sink is the geological term for a "basin in which a river terminates either by evaporation or percolation." Without warning one day, evaporation or percolation ceased abruptly. The water began to rise, and before long the poles were spread over several square miles. It took two men on a raft made of telephone poles several hours to retrieve this valuable flotsam.

When it came to constructing the line through the shallow lakes in this section, none of the post hole machines then on the market would work satisfactorily under the conditions. So one of the telephone men devised a machine like a big auger which did the work perfectly.

UP in the Sierras the gangs stringing wires encountered quite different conditions, with snowfall reported to be the worst in thirty years and temperatures of 40 below. A great part of the supplies was hauled by bobsled, and one of the foremen working in Truckee Pass, where they had seventeen feet of snow, relates that he had to put snowshoes on the horses. In the Spring, this thick mantle of snow turned into floods that swept canyons, changed river beds, and kept the construction men away from their task.

Despite such obstacles, there are many examples of a tremendous enthusiasm pervading everyone having a part in the project. It was soon apparent that it was going to be a race against time, which seemed to increase the eagerness of everyone. We have an instance of this in the record of Foreman Neill Bellingham's gang

HOME ON THE RANGE

This camp, west of Wendover, Nev., is typical of the conditions under which the construction forces lived and the country in which they worked while building the First Transcontinental

at Wadsworth. When they saw what they had to accomplish and how short a time they had for it, they held a council of war. At this it was agreed that success could only be achieved by adhering to a prescribed daily routine. They would roll out at 6, lunch would be on the job, return to camp at 5, and lights out at 9. This was the unalterable daily schedule except that every third Sunday they would stop for a general wash-up.

There was Work to be Done East of Denver Too

MEANWHILE, back East the "Long Distance Lines Department" of the A. T. and T. Company had undertaken a formidable job. It will be recalled that at the time this project was begun, New York to Denver represented about the ultimate in long distance telephony. To extend the limits of the voice beyond this distance meant a complete rehabilitation of the line all the way back to New York.

The reason for this was that the "loading" then used was entirely unsuited for use with repeaters—which had to be employed if greater distances were to be spanned. This loading was accomplished by coils at short intervals along the line, their effect being to reduce the transmission loss. Here again, therefore, the telephone engineer had to produce something new:—an improved type of loading coil.

Moreover, the spacing of the older coils was not sufficiently regular for satisfactory repeater operation. So the Long Lines men began the work of replacing loading coils and respacing them throughout the length of the most direct route from New York to Denver. Respacing loading coils necessitated installing a prodigious number of new transpositions, with the attendant cutting and splicing of wires on working circuits. And because no telephone engineer is content to rely upon a single strand of communication when it is practicable to provide

HEAVY GOING

Humboldt Lake, in Nevada, is little more than a swamp, but it made pole-setting an arduous task

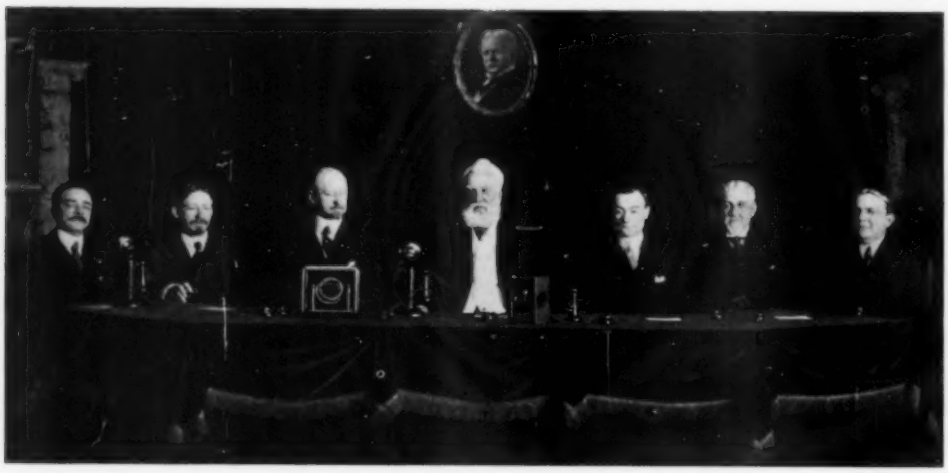
a "second string for his bow," similar operations were performed upon a second route between New York and Chicago.

One extremely formidable problem for the telephone engineers was that of cable. At that stage of long distance telephony, even the small amount of cable necessary to carry long distance lines into or through a city had a serious effect upon the travel-weary currents. Fortunately, it had for many years been the practice in building long distance lines to skirt large centers, as a consequence of which these lines went into very little cable; so that, on a percentage basis, the amount of cable in the line ultimately set up for transcontinental service was what the chemist would call "a trace." The first pole of the aerial wire line was located in Journal Square, Jersey City.

IT would be interesting to go back in time and look at that first transcontinental line through the eyes of the men who had set it up. There it was: four copper wires stretching for 3400 miles, vulnerable to myriad dangers. Just one tiny imperfection —and all coast-to-coast service might be interrupted! All around these wires were a hundred forces, great and small, ready to drain the current off: gales and floods; or a loose connection or faulty insulation making it a prey to those minute enemies, like King Richard's antic Death that comes at the last, and with a little

STRAIGHT ACROSS

The salt swamps east of Wadsworth, Nev., caused no deviation in the directness of the line



IN NEW YORK ON JANUARY 25, 1915

Seated at the table in the offices of the A. T. & T. Co. are, left to right: John J. Carty, Chief Engineer; George McAneny, President of the New York Board of Aldermen; Union N. Bethell, A. T. & T. Senior Vice President; Alexander Graham Bell; Mayor John Purroy Mitchell of New York; C. E. Yost, President of the Nebraska Telephone Company; and Comptroller William A. Pendergast of New York City. In a glass case before Mr. Bethell is a coil of the wire over which Dr. Bell had transmitted his first sentence—"Mr. Watson, come here. I want you"—and at the inventor's left is a replica of his original telephone, which was wired into the transcontinental circuit and over which he spoke a few words to Mr. Watson in San Francisco

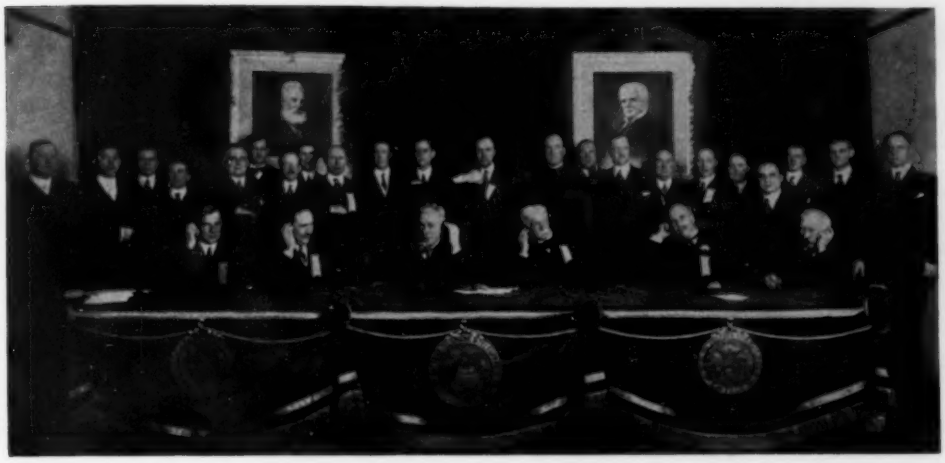
pin "bores through his castle wall, and farewell king!"

That those directing the work were well aware of this is obvious in the provisions they made for patrolling the line previous to important tests and demonstrations. From one coast to another, men were assigned to positions at an average of 14 miles apart, for it must be remembered that the hazards to the line were not confined to the great open stretches of the West and the rocky defiles of the Sierras. The weather in that section can be duplicated on the same scale in the Alleghenies, where snow, sleet, floods, and wind can—and do—mow down a pole line with startling suddenness.

So there was good reason for a solid line of patrols, a regular force totaling around 450 men who, traveling by auto and motorcycle, on horseback or in teams, on foot or on snowshoes, could reach their stations in half an hour—as they did on test mobilizations. An additional 600 men were subject to call.

The Culmination of a Mighty Undertaking

ALL were at their posts, needless to say, or standing by, just a quarter century ago on January 25. Then was at hand the great hour, the dramatic culmination of nearly two years of line construction and of still more years of planning, engineering, lab-



IN SAN FRANCISCO ON THE SAME DAY

In the offices of the Pacific Telephone and Telegraph Company, those seated at the table are, left to right: George E. McFarland, President of the Pacific Company; President C. C. Moore of the Panama-Pacific Exposition; Thomas A. Watson, Dr. Bell's assistant in the experiments which resulted in the invention of the telephone; Thomas B. Doolittle, retired, one of the four incorporators of the A. T. and T. Company; Mayor James Rolph, Jr., of San Francisco; and Chairman Henry T. Scott of the Pacific Company. In the background are officials of the telephone company

oratory research. Then was to be dedicated to public use a telephone line which spanned the continent, made us literally a nation of neighbors, proved beyond doubt the force of that phrase which had till then expressed an aspiration rather than a fact: "universal service."

The importance of the opening of the first transcontinental line to commercial service is attested by the ceremonies which were held on both the East and West Coasts and by the personages who were invited to take part in them.

Seated at a table in the offices of the A. T. and T. Company in New York shortly after 4 P.M. were: Alexander Graham Bell, inventor of the telephone; John J. Carty, Chief Engineer, A. T. & T. Co.; U. N. Bethell, Senior Vice President, A. T. & T. Co.; C. E. Yost, President, Nebraska Telephone Co.; and John Purroy Mitchell, Mayor, W. A. Prendergast, Comptroller, and George McAneny, President of the Board of Aldermen, of New York City.

At a similar table in the offices of the Pacific Telephone and Telegraph Company in San Francisco, the time being somewhat past 1 P.M., were: Thomas A. Watson, who had assisted Bell with his experiments and had manufactured the first telephone under his direction; President G. E. McFarland of the Pacific Telephone and Telegraph Company; H. T. Scott, Chairman of the Board of Directors of the Pacific Company; Thomas B. Doolittle, one of the four incorporators of the A. T. and T. Company, in

1885; James Rolph, Jr., Mayor of San Francisco; and C. C. Moore, President of the Panama-Pacific International Exposition.

Two others, not present in person, were linked by wire with the entire proceedings. Theodore N. Vail, ill, was at Jekyl Island, off the Georgia coast. Woodrow Wilson, President of the United States, was at the White House in Washington.

AT half-past four, in New York, Mr. Carty announced that all was in readiness. Dr. Bell lifted the receiver of the telephone before him—and began conversation with Mr. Watson over 3,400 miles of wire. The line was formally in service!

Midway in the conversation with Mr. Watson, Dr. Bell transferred for a moment from the standard desk instrument to a replica of the original telephone which had first transmitted a complete sentence by wire—and which had been specially wired into the circuit for the occasion. Mr. Watson reported that he could still hear clearly over the line. Returning then to the regular transmitter, Dr. Bell concluded a moment later with this stirring tribute:

"All honor to the men who have rendered this great achievement possible. They have brought all the people of the United States within sound of one another's voices, and united them into one great neighborhood."

At this point President Vail, who had been listening although more than a thousand miles from New York, extended his congratulations to Messrs. Bell and Watson. He then exchanged greetings with President McFarland in San Francisco. Mayor Mitchell and Mayor Rolph then conversed, as did others of the guests in the two cities.

A. W. Drake, then Assistant General Superintendent of Plant, now retired, whose recollections have been of material assistance to the authors in preparing this account, makes an interesting commentary on the inventor's reaction to the ceremony. Of course Dr. Bell was tremendously impressed with the realization that this invention of his had developed to such amazing stature in his own life-time. But what seemed to give him an even deeper satisfaction, as is quite understandable that it should, was that intelligible speech could be transmitted 3,400 miles by a replica of that original instrument which he brought into existence nearly forty years before.

At 5:45 in New York it was announced that President Wilson would speak with Mr. Moore, President of the Panama-Pacific Exposition. To the latter Mr. Wilson extended his congratulations upon the prospects for a successful exposition. Mr. Moore responded with assurances that a most cordial welcome awaited the President in San Francisco.

To Messrs. Watson and Bell in turn President Wilson then said:

"I consider it a great honor to be able to express my admiration for the inventive genius and scientific knowledge that has made this possible, and my pride that this vital cord should have been stretched across America as a new symbol of our unity and our enterprise. . . . May I not congratulate you very warmly on this notable

consummation of your long labors and remarkable achievements? You are justified in feeling a great pride in what has been done. This is a memorable day, and I convey to you my warm congratulations."

And to Mr. Vail the President said: "Before I give up the telephone, I want to extend my congratulations to you on the consummation of this remarkable work."

At eight o'clock (Eastern time) the lines were opened between San Francisco and Boston, and telephone and civic officials there conversed with the group in the city on the western seaboard.

Demonstrating the Service to the Nation

THE official opening was but the prelude to a series of demonstrations that continued for over a year. They linked San Francisco with a score of her eastern neighbors; they introduced to listeners at dinners and meetings a galaxy of famous people: ex-President Taft, General Wood, Admiral Peary, Thomas Edison, and many others. Caruso's voice crossed the continent. Stripped of most of its overtones but still silky gold, it captivated a San Francisco audience—and gave the men at the Salt Lake City testboard something to tell their grandchildren. At intervals during the hour before the show, he would sing a few bars or part of an aria for the men at Salt Lake. "How do I sound?" he would inquire anxiously.

An Indian chief spoke from Winnemucca, Nevada. Two Chinese, in Boston and San Francisco respectively, exchanged greetings, thereby proving that the line was just as good as the one in Dr. Bell's first shop in Boston, where two Japanese had demonstrated that the new device could transmit a foreign language.

There were numerous other "sound effects" featured in these demonstrations. Perhaps the most impressive was the tones of Philadelphia's famous Liberty Bell, transmitted to San Francisco on the day the service was extended to the venerable city that surrounds Independence Square. It broke a silence of eighty years, the bell having cracked while tolling the death of Chief Justice Marshall in 1835.

The two most popular were the sound of surf, and phonograph records. Listeners in San Francisco would be taken by telephone to Rockaway Beach, near New York, to hear the Atlantic Ocean, while the audience in the eastern city would hear the waves roar against the rocks at the foot of the Golden Gate's Cliff House.

The phonograph records were an indispensable property in these demonstrations. It was the hey-day of Sousa and his marches, and day after day, the "Stars and Stripes Forever" and other martial airs vibrated across the continent. Although the technicians who monitored those demonstrations at the repeater stations may not have heard "Stars and Stripes Forever" in all the twenty-five intervening years, it is probable that they could whistle it today with not a grace note out of place.

The demonstrations were a recreation on a national scale of similar work by which Bell and Watson, in the 'seventies and early 'eighties, had made the East conscious of the new instrument that was among them.

Behind it all was the skillful showmanship of John J. Carty, which was nowhere better illustrated than in the "roll-call" with which each demonstration began and ended. As the master of ceremonies called the final roll of the cities along the route, the testboardman assigned to the demonstration circuit at each station signed off with a "Goodnight, San Francisco" —or Salt Lake, Denver, Omaha and so across the country, until that last goodnight from the testboardman at the city where the demonstration was held. It was a feature long remembered by those present at these demonstrations; it was always effective. Indeed, one master of ceremonies stated in his report that at this juncture he had "seen eyes brimming with tears."

THERE were many similar demonstrations in other parts of the country, before service clubs, chambers of commerce, and organizations of every description.

The demonstrations in the Middle West had an interesting character, and noteworthy results. They were under the direction of T. G. Miller, now Vice President in charge of the Long Lines Department, who was at the time Division Plant Superintendent at Chicago, and they covered an area from Ohio to Nebraska. They were a close parallel to those early lectures of Bell and Watson, for the "show" traveled from town to town in an endless succession of "one night stands" for a period of more than a year. These demonstrations frequently employed several hundred receivers, and according to J. J. Pilliod, now Engineer of Long Lines, who was the engineer on location, they were often wired up for an evening's presentation with a celerity that matched the work of experienced stage-hands.

All these demonstrations were a truly remarkable testimony to the thoroughness of those who had engineered and built this line, and to the alertness of those charged with operating the equipment. In a total of more than 1500 demonstrations the failures were almost negligible. Take the daily shows at the Panama-Pacific Exposition, which began when the Fair was opened and continued well into 1916: the record shows that 1,177 programs were put on; five a day except on Sundays. Only nine shows were cancelled on account of line trouble, and 35 demonstrations were given from Denver instead of New York because of trouble east of Denver. An equally creditable showing was made on the other demonstrations. And there can be no doubt that this fact made a profound impression upon the public mind as to the dependability of this new system and of long distance service in general.

While these spectacular and convincing demonstrations of the first transcontinental line's capabilities were continued for many months, the line was made available for public use within a few hours after the conclusion of the dedicatory ceremonies: at 12:01 A.M. on January 26 in New York—which was, of course, 9:01 P.M. on January 25 in San Francisco; and several commercial calls between the Atlantic and Pacific coasts were handled during the next 24 hours.

Service was Limited at First by Several Factors

THE early service over the First Transcontinental was decidedly limited, however. Under the rules followed by the Long Lines traffic department in the early stages, the only calls that were accepted unconditionally were between New York, Boston, or Washington, and San Francisco. For the purpose of passing upon the feasibility of transcontinental calls to other points, a bureau was established at the New York long distance office, the eastern terminus of the line. Here the transmission problem was canvassed and a verdict rendered.

There were good reasons for this selectivity in accepting calls. The frequency band transmitted was narrow by comparison with that of a modern circuit, producing a voice effect that resembled the early phonograph records. There were wide fluctuations in the efficiency of the circuit with changes in the weather—and there was always lots of weather at one place or another along this 3,400 miles of line. And there was a very definite limit to the volume that could be produced at the end of the line, for increase in amplification beyond a certain point caused repeaters to howl.

IN addition to these technical matters, there was always to be considered the operating procedure, which called for "switches." At the beginning, the number of coast-to-coast calls did not warrant a direct circuit, so that a call from New York to San Francisco was completed by putting together a series of separate circuits. The switches on the First Transcontinental were at Chicago, Denver, and Salt Lake City. There were thus four separate pieces of the line to be put together; and if the call involved some other point beyond New York or San Francisco, there were five. This meant, of course, that before the call could be completed there must be at least one idle circuit in each of the segments. Under these conditions, delays in completing calls were inevitable.

In the early stages of transcontinental service there was an average of about two calls a day. But it was foreseen that this tiny stream would expand to large proportions, to carry the flow of business and social intercourse between the two sides of the continent.

Service and the Demand for It Grew Together

IN the early 1920's, traffic between the East and Southern California was developing rapidly; by that time, something like half of the calls over the cross-country line involved points in the latter region. Meanwhile, technical developments had been proceeding apace. Repeaters, filters, and networks of new design were made available and these, more frequently spaced, permitted removal of the open wire loading. The non-loaded wires—capable of transmitting a wider frequency band and having smoother impedance characteristics and a higher speed of propagation than loaded wires—in conjunction with the new equipment provided circuits noticeably better in quality and stability of performance. Transcontinental service was now ready to

expand beyond its early limitations. Engineers already saw not one but four routes between East and West.

The next step was the establishment in 1923 of a second route from Denver to California, extending south through El Paso. Crossing the barren lava beds and mesas of New Mexico and the bleak region of southern Arizona, where the shifting sands sometimes build up to within a foot or two of the wires, this route traverses the Salton Sea section, some 200 feet below sea level, and so to Los Angeles. The use here of carrier current telegraph systems provided needed additional telegraph facilities.

Two years later another important link was forged on this route, when wires were strung eastward from El Paso to Dallas. This, with existing lines through Little Rock and Joplin, established another route to the coast from Chicago, known as the Southern Transcontinental route. Other extensions in the South eventually completed an excellent trunk route across the entire southern part of the country.

A major improvement in coast-to-coast service came in 1926 with the placing in operation of carrier telephone channels between Chicago and Sacramento over the Central Transcontinental route, making it possible to set up three additional talking circuits of high quality over a single pair of wires.

By this time, the development of the Northwest made it desirable to provide a route across the northern part of the country to Seattle. Here it was necessary to reconstruct a great part of the existing lines and to string new wire over much of the 1800 miles from Minneapolis to Seattle. Most of this work had to be done in the summer months on account of the long and rigorous winters and the rugged mountainous terrain of that region. Along this route carrier telephone systems were also installed. This line, known as the Northern Transcontinental route, was placed in service in 1927.

BEFORE passing on to the fourth and newest link between the two coasts, we might look over the eastern section of the country and observe the changes that had been taking place there. Chief of these was the improvement and extension of cable facilities. By 1927, cable facilities were available as far west as Chicago and St. Louis which were suitable for transcontinental business. Gradually spreading over the eastern part of the continent, these cables provided a virtually storm-proof network along the trunk routes. Coming down to the present time, it is significant that in today's transcontinental calls, about 45 per cent of the mileage is in cable, whereas in the original circuits, cable was used for less than one-half of one per cent of the distance.

One more telephone span has been thrown across the country: the Fourth Transcontinental, completed in 1937. This line runs westward from Oklahoma City through Amarillo and Albuquerque, joining a cable in California which carries wires into Los Angeles. The outstanding feature of this line is that it provides for the use of a new and improved type of twelve-channel carrier current telephone system, using frequen-

cies up to 140,000 cycles. This new equipment, together with the three-channel carrier equipment previously available, makes it possible to handle simultaneously over a single pair of wires a total of sixteen individual telephone conversations.

The Developments of a Quarter of a Century

A FEW statistics on these wire spans across the country will form an interesting contrast with the tenuous link first provided in 1915. There are now about 170 circuits across the western states, available for transcontinental telephone service. Approximately three-fourths of these are carrier current channels, providing voiceways of excellent quality. Thousands of vacuum tubes insure adequate amplification. Direct circuits from coast to coast give a speed of service that normally averages less than two minutes from the time the long distance operator answers until the start of conversation. (This compares with a delay of about an hour in the early years.) Recognition of these improvements is seen in the fact that during the period of transcontinental construction, traffic between the Pacific Coast and the rest of the country grew twice as fast as the total Long Lines traffic. And there is one more statistic that has had a not unimportant part in this trend: When the New Yorker put in a call to San Francisco in 1915 it cost him $20.70 to talk for three minutes. Today the day station-to-station rate for the same call is $6.50, while the night and Sunday rate is but $4.25.

Speed of service, ease and clarity of transmission, reductions in rates, multiplication of circuits—all these improvements have been brought about in the past 25 years. To them the public has responded with an appreciation of the greater value of the service which has manifested itself in ever-increasing use. Whereas the average over the new line during its first year of operation was two calls a day, now on the average about 1,700 calls a day flash back and forth between the Pacific coast and points east of Denver.

THIS account of the building of the first transcontinental line, and of the extensions of the service in the years since, has necessarily been primarily a story of physical growth. It would be incomplete, none the less, without some mention of the social implications of this tremendous web of wires spreading out over mountain and forest and desert, linking tiny hamlets and great cities. Over it go telephone conversations, the radio programs of the broadcasting networks, the telegraph and teletypewriter messages of business, government, and the press, and even pictures of events happening a thousand or three thousand miles away but a few moments or hours before, in a never-ending flow. More than a thing of wire and poles and repeaters and supplementary apparatus of all sorts is this transcontinental network: it is a communication system, nation-wide and nation-serving, of a completeness, flexibility, and dependability not to be matched throughout the world.

III. TRANSCONTINENTAL PANORAMA*

From the Solution of the Specific Problems of Transcontinental Telephony Have Come Changes and Advances in the Art Which Have Affected Every Aspect of the Service

By FRANK B. JEWETT

As a topic this evening I have chosen the epoch of transcontinental telephony, because it was twenty-five years ago last July that the first transcontinental circuit carried its first conversation, and it will be twenty-five years ago next January that the first transcontinental line, which consisted of three circuits, was opened for public use.

My choice, however, is based upon much more than a mere desire to commemorate a now far-off event, propitious though such a gesture may be. I hope that in the course of my remarks I can portray this early telephone line for what it was in fact: the progenitor of much that has taken place in the last twenty-five years in a very active sector of electrical engineering. It marked the dawn of a new era in electrical communication.

As we review the history of this period, we shall witness new physical appliances recasting not only the technological side of a business but its traffic and commercial aspects as well. I hope to make clear to you the interplay of technological and economic factors over a considerable period of time to the end that copper and iron in huge quantities have been replaced by minute electron streams in vacuo; and, further, that the attenuation of telephone currents, once the quintessence of the telephone engineer's troubles, can now be pushed to levels hundreds of times higher than the early limit before it becomes comparable with the other economic factors involved.

In any general survey of the changes and improvements which have altered the art of telephony during a period of time or have flowed from the successful solution of a specific problem, one must always have in mind the ultimate objective of commercial telephony. This objective is simply stated; the attainment of it even approximately is a long, hard road. From the day when men of vision realized the potential possibilities of Bell's invention, the ultimate technical objective has been a service at once so extensive and adequate that any one, anywhere, at any time, and on demand, could talk to any one, anywhere else, with ease and clarity.

* The Steinmetz Memorial Lecture, delivered before the Schenectady Section of the A. I. E. E. on November 2, 1939.

Added to this has always been, of course, the economic and social objective of a cost so low as to offer no substantial bar to an essentially untrammeled use of telephony by any one who has occasion to talk with another at a distance.

For the Bell System as a public service agency, all this is succinctly stated in the frequently quoted objective of the best possible service at the lowest possible cost consistent with financial stability and fair treatment of employees. When, however, one attempts to translate this broad objective into the concrete technical terms needed for its fulfillment, the phraseology is quite different.

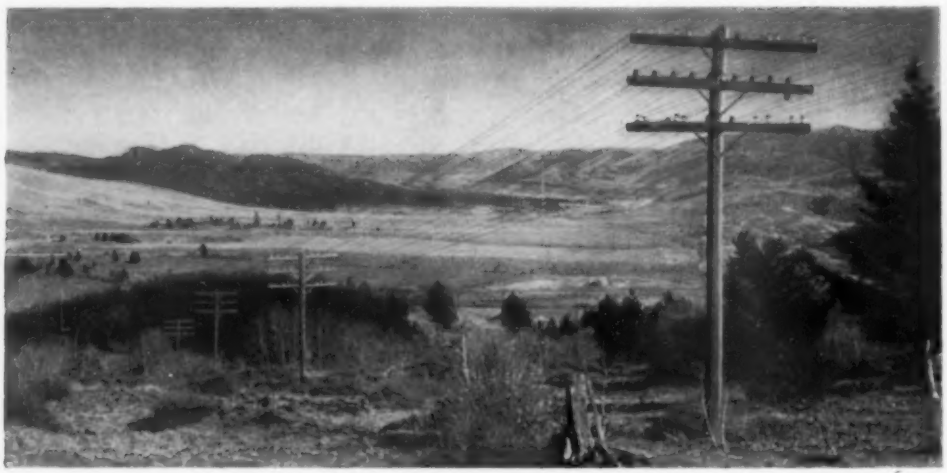
For the research man and the engineer, the goal is one compounded of a transmission art so perfect that distance *per se* is no barrier; that telephone circuits and all that they require in auxiliary apparatus for proper operation can be produced so cheaply as to be available in the profligate numbers required for a universal no-delay service; and, finally, that the vast society of Lilliputian currents must live amicably with each other tightly packed together in a world of Brobdingnagian interference.

It is a distant goal even when viewed through the glasses of perfection which picture direct circuits for every desired connection. It is doubly distant when his practical senses tell the scientist and engineer that they must attain part of the solution with indirect switched circuits and, further, that these switches must neither delay the service nor affect its quality appreciably.

The goal of perfection is still ahead, but we have made astounding progress toward it in the quarter century since the first voice spanned the continent. In very large measure this progress is directly the result of developing fully the latent possibilities of the physical instrumentalities unearthed in the search for an answer to transcontinental telephony. There may seem to be little connection between the quest for an amplifying device to solve a specific transmission problem in 1914 and an engineering study in 1939 to work out a nation-wide traffic routing system, and yet one is the direct lineal descendant of the other.

A Structure No One Has Ever Seen Entire

In considering the evolution of telephony, I must remind you that we are dealing with a structure that does not lend itself to pictorial representation. I wish this were not the case. I wish that it were possible to throw on the screen here a lantern slide that would depict a transcontinental line and upon which I could, by appeal to your eye, assist you in visualizing the additions and changes which mark the progress of a quarter of a century. When one attempts by word of mouth to explain the problems of telephony and how they have been and are being overcome, he has, I must admit, a uniquely difficult piece of work in hand. He must reduce to words—and I know that you would prefer not too many words—a structure which not even he himself—let alone any one in his audience—has ever seen in its entirety. Likewise, he must put into words as best he can a host of concepts which find their proper expression only in mathemati-



THE NORTHERN ROUTE

The most northerly of the transcontinental lines crosses the Continental Divide at McDonald Pass, west of Helena, Mont. This view is to the East from just below the summit

cal symbols and processes or in the specialized language of the physicist.

If I could transport you rapidly, magic-carpet-wise, out across the continent three thousand miles or so, thus enabling you to visualize what a complex thing is this creation we are to consider this evening, I might hope to convey to you at least a superficial conception of its elaborateness and seeming fragility. Only in this way, I am sure, would you fully sense how remarkable it is that this far-flung and delicate structure should be endowed with surprising electrical stability and immunity to meteorological and man-made interference.

LET us at the outset imagine a single pair of wires extending out of the window and thence across-country for hundreds or even thousands of miles; and let us bear in mind that these wires, by virtue of their length, have become possessed of considerable amounts of distributed capacity, inductance and leakage—and are, in addition, subject to a variety of induction effects from paralleling communication and power circuits.

Moreover, in many instances one or both pairs of wire are packed tightly together with many similar pairs and enveloped in an impervious lead sheath to form a cable in which a neutral gas, such as nitrogen, is maintained under pressure, and which, should a leak in the sheath develop, operates an alarm circuit to sound a distant SOS. We must also note the presence, on many of the pairs, of loading coils spaced at regular intervals varying from about five-eighths of a mile to one and one-eighth miles, depending on the type of cable.

Each loading coil is a winding of wire on a special magnetic core. Its function is to assist the speech currents, as they travel, to overcome the large attenuating effect of the elec-

trostatic capacity of the tightly packed wires. These coils, of which there may be as many as two or three thousand called into play in the handling of a single message, must be electrically identical to a very high degree.

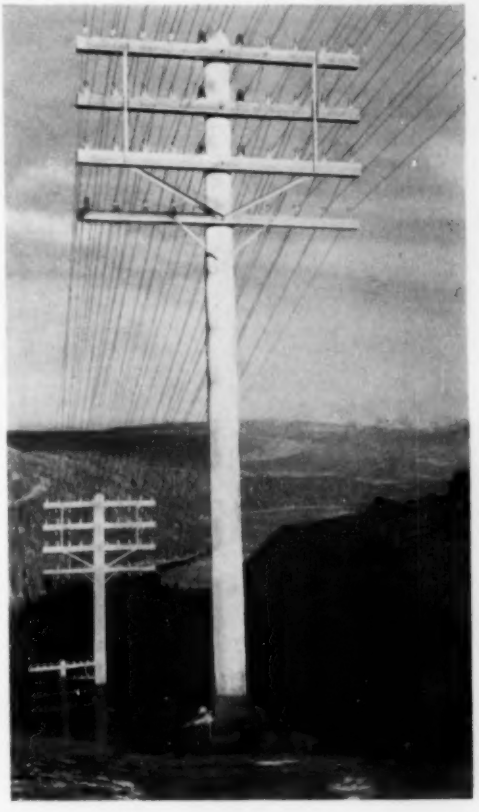
Next, there is the repeated and uniform twisting of each pair of wires at its own particular pitch to secure such nicety of balance, both electrostatic and electromagnetic, that not more than a millionth of the power of a telephone circuit will pass over inductively to any neighboring circuit.

Then at intervals of fifty miles for certain types of cables, and at shorter intervals—even as low as five miles on certain newly projected types—we would encounter the thermionic amplifiers which restore the message energy after attenuation by resistance and other forms of dissipation. Closely associated with certain of these amplifiers are other devices which suppress electric echoes or which automatically counteract the effect of changes in conductor resistance induced by changes in temperature.

So much for our imaginary flight! Many of the features of a long telephone line which I have just enumerated are comparatively recent accomplishments; they project me somewhat ahead of my story. We must return to the year 1914, when a long distance telephone line consisted of a pair of large copper wires strung in the open and with magnetic loading coils spaced along it at intervals of eight miles.

The Need for an Amplifier Was Fundamental

THE day of speech current amplifiers had not arrived, except for a carbon microphone type which, because of distortion, was applicable only as a single stage amplifier on non-loaded lines. Every long circuit operated essentially upon the basis that no energy came out at the receiving end which was not introduced at the sending end—and, needless to say, very little of that. It was also neces-



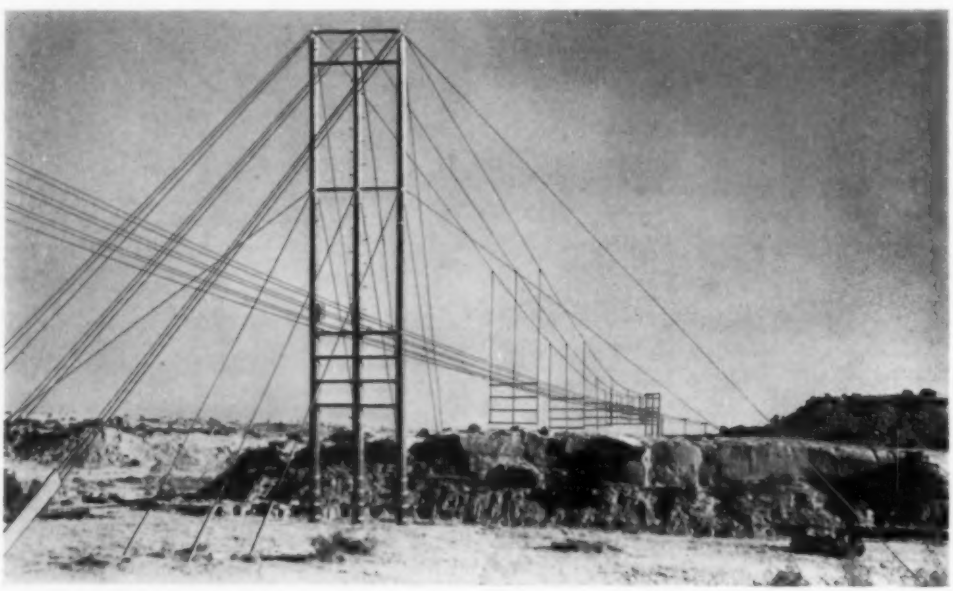
THE "CENTRAL TRANSCONTINENTAL"
The line is shown here at Donner Summit, Cal., with Donner Lake in the central background

sary to preserve enough of the energy of the various frequencies represented in speech so that intelligibility was not sacrificed: a requirement which added appreciably to the problem.

With the use of 8-gauge hard drawn copper line wires (weighing 870 pounds to the loop mile) augmented by loading, it was just possible to carry on a conversation between New York and Denver. How slight the margin of safety was in that line is well illustrated by the fact that it had an equivalent of about 35 decibels, so that the power at the receiver amounted to only about 1/4,000 of the power sent out by the transmitter. On this same basis a telephone line spanning the continent would have yielded only 1/100 as much power at San Francisco as at Denver; i.e., about 1/400,000 of the power.

A comparison of these two figures shows at once that there was no hope of solving the problem of transcontinental telephony by some scheme which would apply to the circuit a larger power than the typical telephone transmitter. Any feasible solution must necessarily involve some sort of current rejuvenation at several points intermediate between transmitter and receiver, since the use of heavier copper was economically unsound: in other words, tandem amplification, with all its obvious difficulties, was the only way out.

THE search for a successful amplifier or repeater extended over years, and almost simultaneously three promising devices were brought to the point of trial: one, an improvement of that already mentioned, was a me-



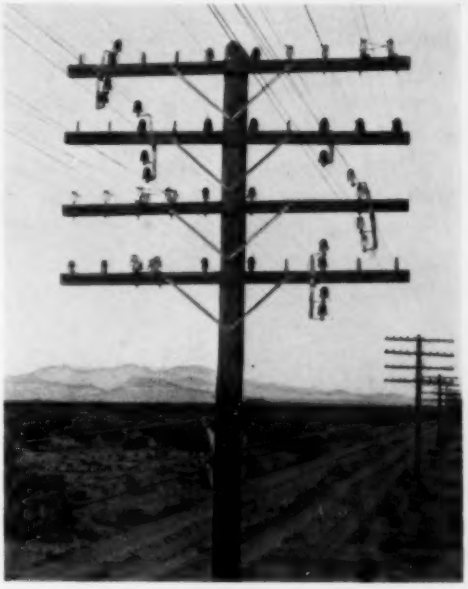
"LARGO NO. 1" ON THE FOURTH TRANSCONTINENTAL LINE

This photograph has been retouched to show the catenary suspension of the wires over this "dry wash," which is well but not favorably known to telephone men in the territory. It lies west of Tucumcari, N. M.

chanical structure which used the amplifying property of the carbon microphone; one a low pressure arc which possessed a negative resistance characteristic; and, finally, one which employed an electronic current controlled electrostatically by a grid of metal wires placed athwart it. I need not add that this third arrangement was derived from the audion of Lee DeForest, which he was then using to receive radio signals. That was more than a quarter of a century ago, when the science of thermionics was in its infancy.

To those of us who were concerned with the problem of the telephone repeater at that time, it was far from evident which of the three alternatives would ultimately win in the struggle for existence. Engineering, I need scarcely remind you, is full of questions of merit quite like the one presented by the repeater, and the answer is seldom to be got except on the basis of experience. Naturally, our recourse was to practical tests. The equivalent of a transcontinental circuit was arranged in such a way that each of the three types of repeaters could be switched in and out readily, and extended trials were instituted.

IN this case the answer was not long in revealing itself. The behavior of electronic vacuum tubes designed especially as telephone amplifiers left no doubt that it was at once satisfying in its then performance and full of promise as to additional applications in the future. As we look back upon that situation in the light of our present knowledge, perhaps our wonder is that so recently the ubiquitousness of the vacuum tube should have lain unrevealed.



THE "SOUTHERN TC"

Here the line is crossing arid, cactus-covered plains west of Tucson, Ariz.

We must, however, bear in mind that it employed a high vacuum and that pumps for creating such, even within the physics laboratory, were but lately introduced; moreover, that it also contained a fragile filament—sometimes coated and sometimes metallic—which served as electron emitter and which was subject to little-understood vagaries. The making of vacuum tubes, far from being a factory process, was one which called for the skill and personal supervision of the laboratory; and even after this bestowal of care, the filament might fail in a few hours or a minute leak might destroy the vacuum and thus end the life of a device upon the making of which many anxious hours had been expended and on whose relia-

bility the integrity of service depended.

I REALIZE that these few words will give but a very imperfect picture of the task confronting those who undertook to adapt DeForest's audion to the work of the telephone repeater. Unless one has tried with a molecular pump (so-called) and a liquid air and charcoal combination, and aided by baking and bombardment, to drive a seemingly endless amount of gas out of glass walls and metal plates and grids of a tube, and yet leave the activity of the filament coating unimpaired, he can scarcely realize the hurdle which the telephone engineers of nearly thirty years ago had undertaken to clear. And suppose an experimental line were to prove workable, what chance would there be, considering the highly personalized production techniques and the final fragile character of the vacuum tube as then constructed, that the line could ever be more than an unreliable appendage to a network of shorter circuits?

Before an audience which is as familiar with sturdy vacuum tubes as it is with incandescent lamp bulbs, it becomes impossible to recount twenty-five years' progress step by step with the intention of finally revealing the present status in climactic fashion. You think little more of multi-electrode tubes than you do of bolts and nuts, and complex modulator and control circuits are as much the order of the present day as dry cells and magnetos were a generation ago. I shall, therefore, not attempt any dramatic effect. Instead, my objective will be, by dealing in engineering values, to bring out the interplay of the more significant factors, tracing the line of development and argument which has completely remade the technique and the instrumentalities of long distance telephony.

Before closing this reference to the history of the vacuum tube itself, I should like to say, however, that the telephone engineers were not alone in realizing its potential usefulness, and I know it will come as no surprise to most of you that very important contributions were made at the research laboratory of the General Electric Company here in Schenectady. As a matter of fact, a nip-and-tuck race was run between the engineers at the Bell Telephone Laboratories in New York City and those in the General Electric Laboratory here. I cannot refrain from smiling as I look back upon those days. It seems to me that each group was making such rapid progress that they naturally felt after each new success that at last they must necessarily have out-distanced their rival—and were a bit disturbed to discover, in due course, that the adversary was still abreast.

What the Amplifier Has Done for Wire Economy

As I have already hinted, the advent of the vacuum tube amplifier radically changed the point of view of the engineer regarding long distance telephone lines. Over a period of years he switched from a policy of extreme parsimony to one almost of prodigality. Where initially his every thought had been to design his lines so as to minimize the possibility of energy loss at every point, he later chose smaller and smaller line wires

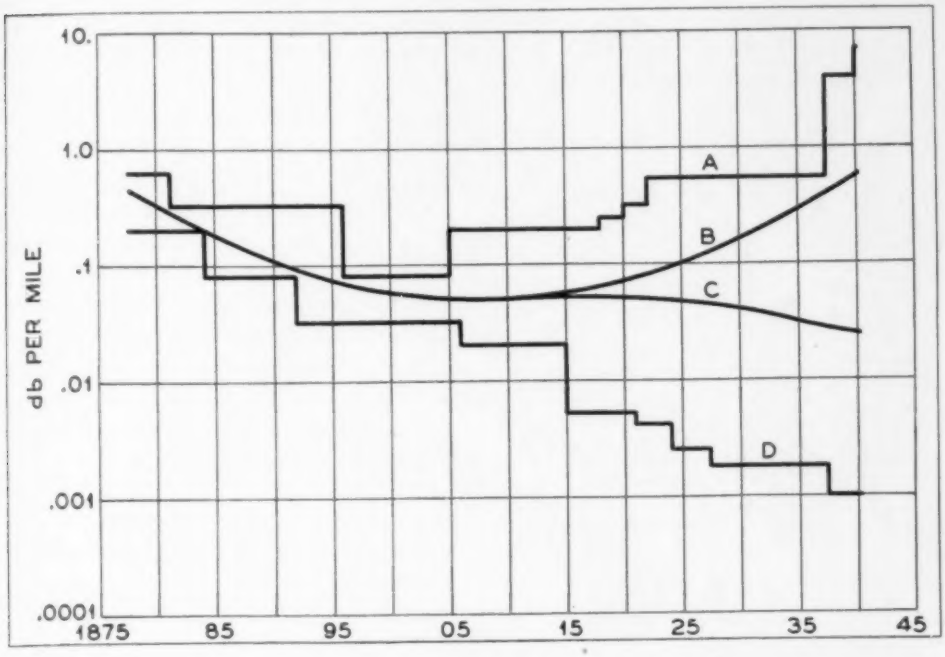


FIGURE 1

Curve A represents long distance circuits possessing the highest attenuation per mile. The extreme for 1940 represents the coaxial cable now being installed. Curve D represents circuits possessing the lowest attenuation per mile after repeaters have been taken into account. Curve B represents the average of all long distance circuits without repeaters, and Curve C represents the average with repeaters

deliberately because the saving on copper more than compensated for the additional amplification entailed. Figure 1 will be of interest in this connection. On it (plotted to a logarithmic scale) the ordinates represent loss per mile of circuit.

Let us consider curve B first; it shows the average loss per mile of long distance telephone circuits as it has varied over the years. You will note that during the period from 1880 to 1915 the average loss per mile fell, the reason being that heavier and heavier copper was resorted to. Then, in 1915, with the advent of repeaters, the circuit attenuation begins to mount, since lighter copper and higher frequencies could be employed. On the other hand, you will note that curve C, which represents the over-all loss including repeaters, still continues to decline. Curves A and D represent the extremes of loss in individual types of circuit.

Prior to the repeater, the loading coil was of paramount importance as a conserver of the power of the telephone currents. As so frequently happens in engineering design, this economy was not always to be obtained without paying a toll. For instance, in the first transcontinental line loading had to be pushed to such

TABLE 1

VOICE FREQUENCY REPEATERS INSTALLED IN BELL SYSTEM

Year	*Total* *
1908	16
1910	41
1915	136
1920	1,250
1925	7,500
1930	80,000
1935	102,000
1938	107,000

* As of December 31

a point that a serious degradation of speech quality resulted. The more heavily loaded a telephone line—that is, the larger the inductance of the loading coils associated with it—the narrower becomes the band of frequencies which the line can transmit. It was the discovery of this effect of loading that led a few years later to the invention of the electric wave filter. It happens that the discovery was made mathematically by Dr. George A. Campbell—who has but recently retired from the Bell Telephone Laboratories' staff. He it was who saw the possibility of simulating and generalizing the effect of a long telephone line, by lumped inductances, capacities, etc., to the end that very compact electric wave filter circuits could be constructed. A little later I shall have more to say regarding the present-day uses of these filters.

Returning to the first experimental transcontinental line of 1914, it included three repeater units, placed at Pittsburgh, Chicago, and Denver, respectively. These, when supplemented by very heavy loading, were just sufficient to make the circuit usable. The quality of speech transmitted left much to be desired, however, for the inductance of the loading coils was such that an effective band of speech frequencies only about 900 cycles wide could traverse the line. This is to be contrasted with a band about 2,500 cycles wide which is handled by ordinary circuits today, while those that are employed for interconnecting broadcasting stations may transmit a band three times this latter figure; and even this is but a fraction of the band of carrier frequencies that a multi-channel carrier system will transmit.

THE original transcontinental line with but three repeaters was purely experimental. It proved, however, that the country could be spanned telephonically, and it also established the supremacy of the vacuum tube amplifier as against the arc and the carbon microphone. Shortly after commercial service started in 1915, six repeaters were substituted for the original three, and these were, of course, spaced about as uniformly as the location of cities and towns would permit. The line itself had a loss of about 60 decibels and the repeaters gave a gain of about 40 decibels. Of course, the day of unattended repeaters and automatic gain control was still undreamed of. Even with six repeaters it was necessary to retain heavy loading, so that the original line represented about the allowable minimum in speech quality.

But the vacuum tube quickly revealed itself to be a fertile subject for research. Over a period of a few years, more efficient and much longer life filaments were discovered, and improved assembly methods were de-

vised as well as rapid methods of evacuation. Thus it became possible, step by step, to be more generous in the use of repeaters in the long distance telephone plant. Table 1 traces history from this standpoint. With success accumulating behind us, particularly by way of improved repeaters and enhanced knowledge of how to operate many repeaters in tandem, it was not long before we overhauled the original transcontinental line, removing the loading coils altogether. Thus, the one device which a few years before symbolized long distance telephony had now begun to slip.

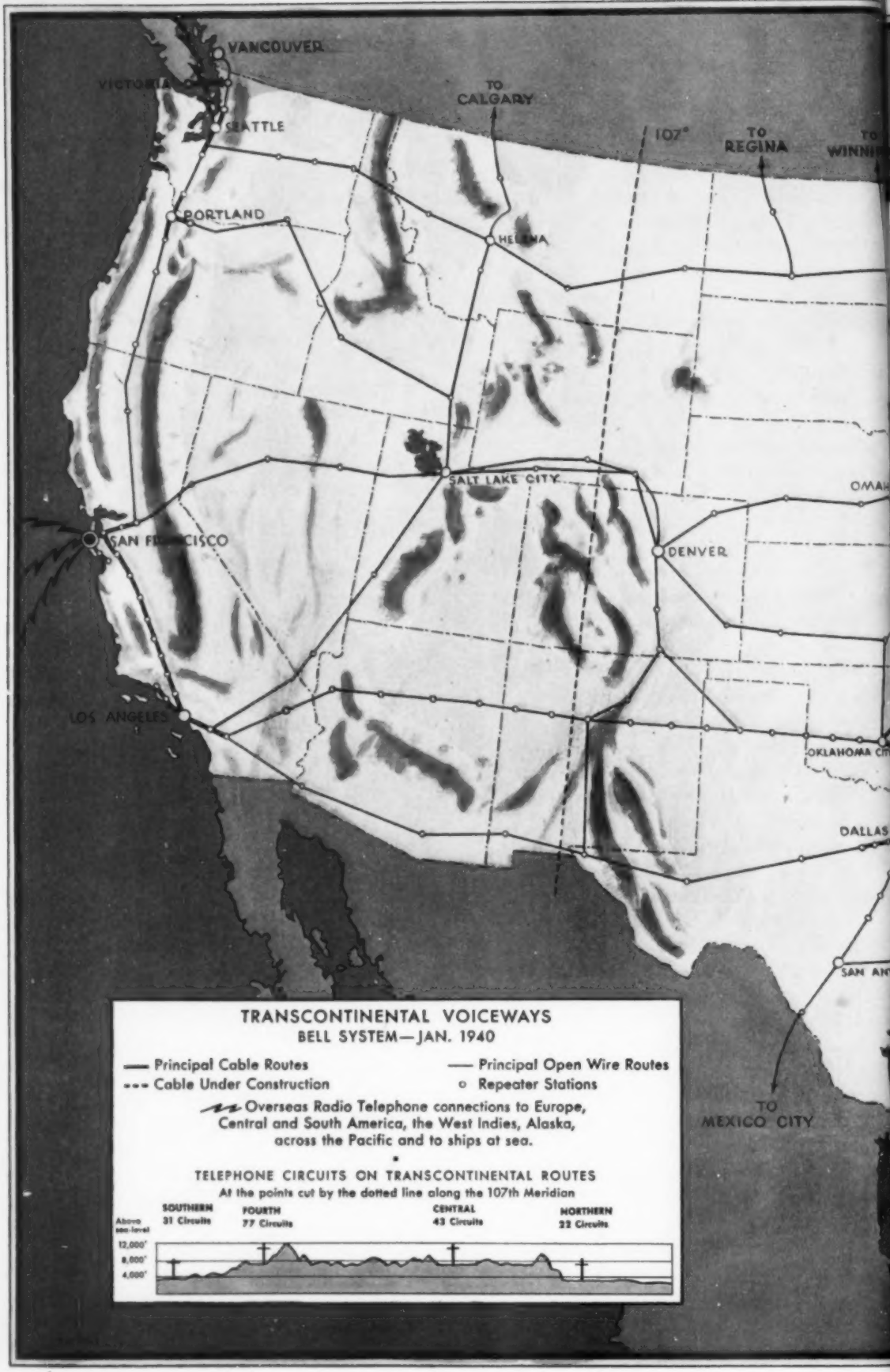
Coil removal from the transcontinental line was dictated by a desire both to improve speech quality and to obtain more circuits. The *demand* for service was increasing in response to *improved* service, and removal of the loading introduced the possibility of multiplexing the lines with carrier systems, so where we had originally possessed only three circuits we could now operate about nine.

At the same time, of course, repeaters were becoming more and more the order of the day on circuits of intermediate length. You will have gathered this from Table 1. In fact, the importance of the repeater is in considerable part due to the changes it has been instrumental in working in the entire toll plant, short haul circuits as well as long haul. As illustrating this and also illustrating the degree to which it has enabled telephone engineers to plan their circuits on a basis other than the early one of conserving the ingoing transmitter energy, I should like to mention a toll project employing cable with small gauge conductors which dates from about 1920; that is, five years after the initial transcontinental success.

Repeaters and Cables

In a cable, due to the fact that the wires of each pair are close together and therefore display large electrostatic capacity compared to an open-wire pair, the attenuation is great unless very heavy conductors are employed. Even then the distortion in non-loaded cables is great, and so for many years prior to the repeater cable was anathema in toll circuits. In other words, so long as the initial ingoing energy was all that could be invoked for reproduction of the message at the receiver, cable was generally rejected.

Nevertheless, cable possesses other virtues so obvious that the toll engineer always eyed it with the deepest envy. Circuits in cable are inherently stable because they are protected from atmospheric moisture. They are also less liable to breakage and to inductive disturbances from paralleling circuits, notably power lines. However, the full virtue of a cable is not realized until the density of traffic becomes large enough to require a large group of circuits. A full-sized toll cable, for instance, may contain as many as 300 or 400 separate lines, and as a normal daily message capacity of a single circuit is perhaps thirty to forty, the potential capacity of such a cable is very considerable. It developed, however—and perhaps it was one of those fortunate coincidences—that by the time a cable became feasible from the technical point of view, the demand in the regions of



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TO AS *FIGURE 2* IN TH

CONTINENTAL CIRCUITS REPRESENT THE CABLE NETWORK REFERRED
ACCOMPANYING ARTICLE

denser population had risen to a height to justify it economically.

OMITTING reference to an early heavy wire cable between Boston and Washington, which was operated without repeaters and which was installed because it was deemed important to have unfailing telephone service along this portion of the Atlantic seaboard, the first repeatered cable (and it was therefore one employing relatively small gauges of wire) was placed between New York and Pittsburgh, with the plan of extending it as need arose to Chicago and perhaps to points farther west. The New York–Pittsburgh section was engineered in 1920 and went into service in 1922, seven years after the transcontinental trial had affirmed the value of the repeater. Today, so rapidly has the demand for long distance telephony grown, that we have not simply a spur of toll cable, but a system which may, without exaggeration, be referred to as a network. As you will see from Figure 2 (pages 48–49), it runs from Maine to Georgia and Texas, and as far west as Omaha and Dallas, and interconnects the important cities of the eastern half of the country.

Twenty-five Years of Progress Against Attenuation

IT might be interesting to digress for a moment at this point, so that we can see how far we have progressed over a period of twenty-five years in the attack upon attenuation. You will recall my having mentioned that the original transcontinental line had an attenuation of 60 decibels, of which about 40 decibels were neutralized by six repeaters. Large line wires and loading coils were employed to minimize to the limit the part to be played by the amplifying elements in the circuits. How vastly different the situation is today will be apparent when I tell you that the attenuation of a cable circuit connecting New York and Pittsburgh is 200 decibels, while for one connecting Boston and Dallas it is 1,100 decibels.

Lest you are not all familiar with the decibel as a unit of attenuation, I will say that to write these results in the form of fractions gives, for the first, 10^{-20}, and for the second 10^{-110}. In other words, a telephone message in traveling from Boston to Dallas must receive a 10^{110}-fold amplication in order that it may be compensated against the incursions of attenuation. If this enormous amplification had all to be applied at the sending end of the circuit, there probably wouldn't be enough energy in all the coal reserves of the earth to do the trick. Success lies in doing a little bit at a time, for between Boston and Dallas there are some 45 repeater points (the precise number depending upon the routing) and the average gain of a single repeater is about 23 decibels, or about 200-fold on an energy basis.

I MIGHT as well disclose to you at once, however, that such figures as I have just cited are mere child's play nowadays. There is adequate justification in numerous instances for undertaking the multiplexing of cable circuits by the carrier principle. Not only does such an arrangement effect further economies in copper and lead, but what is perhaps more important, the transmission of the high frequencies of carrier systems involves the

removal of all loading coils. This, to be sure, causes the attenuation to mount, but a compensating gain appears in reduced time of transmission.

Loaded cable circuits possess a relatively slow speed of propagation—perhaps 10,000 to 20,000 miles per second—with the result that, for the longer circuits, the echo which returns to the speaker from the far end of the cable lags sufficiently in time to be extremely disturbing. To avoid the echo difficulty, the longer loaded cable circuits are equipped with so-called echo suppressors, which operate to permit propagation in only one direction at a time, and are controlled, of course, by the person who first starts talking after any pause. But with non-loaded cable circuits, including all equipment, the speed of propagation jumps to around 100,000 miles per second—more than half the speed of light in free space—with the result that except on extremely long circuits the echo is not separable by the ear from the inducing sound.

BUT what of the attenuation? It seemed high enough on *loaded* cables. It naturally jumps many fold, but not more than the capacity of repeaters to counteract. Circuits are in daily use in which the attenuation is as much as 2400 decibels, and experimental lines have been formed and operated by the looping back and forth of several cable pairs to build up the equivalent of an 8,000-mile straightaway whose total attenuation was about 12,000 decibels. Such a circuit needs a total amplification, on an energy basis, which amounts to 10^{1200}, a ratio so enormous that it quite transcends ratios such as the size of the total universe to the size of the smallest known particle of matter.

Naturally, the problem of balancing this huge amplification against the correspondingly huge loss to the required precision, 1 decibel or 2 decibels, is difficult. Fortunately, a new form of amplifier employing the principle of negative feedback—it is an arrangement with which some of you are doubtless familiar—was invented by Mr. H. S. Black of the Bell Telephone Laboratories, which has enabled us to solve the problem. By using Black's negative feedback we are in possession of amplifiers giving 50 to 60 decibels gain with a variation of not more than .01 decibel with normal battery and tube variations. I might also say that were it not for such a repeater, the coaxial type of cable, which again possesses attenuation of the order we are now considering, would be quite impracticable.

TIME will permit me to do no more than mention in passing the fact that those large amounts of gain must be controlled automatically, particularly in response to temperature changes. Cable circuits, by their nature, show only minor variations in capacity, inductance, and leakage, but the resistance of their conductors can change by large amounts from winter to summer, and even from hour to hour. These changes are, of course, more rapid in the case of overhead cables than in those placed underground. However, in each, automatic regulators which take their cue from so-called pilot wires running through the cable along with the speech pairs are necessary. Thus, the annual variation found upon a cable circuit

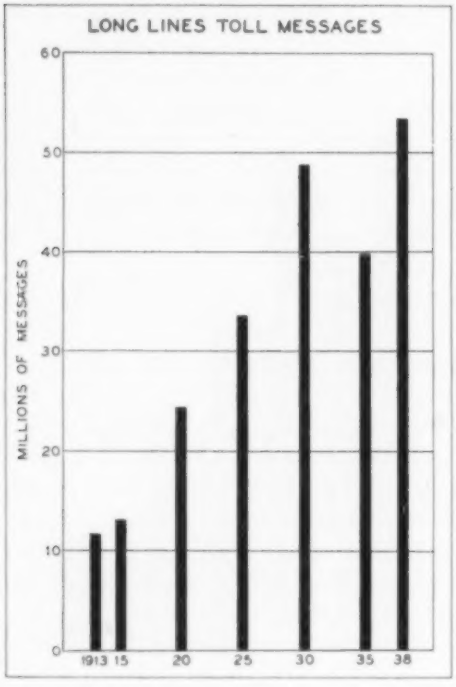


FIGURE 3

Twenty-five years of long distance toll traffic

may be as much as 100 decibels, or more than the entire attenuation of the first transcontinental line. In fact, the variation experienced on some of the long carrier channels is as great as 250 decibels.

Now, you will have assumed already that with the introduction of toll cable, together with carrier systems for both open wire and cable circuits, there must have been a steady and supporting growth in the demand for long distance telephone service. To give you some conception of how rapidly our toll traffic has grown, I shall have recourse to another illustration (Fig. 3). Over the period of the last twenty-five years, the American public truly seems to have become long distance-minded. This illustrates what, to my mind, is one of the important principles of engineering. We see it exemplified in many lines of industry, namely, that the volume of demand is governed by a complex assemblage of such factors as cost, convenience, ready availability, etc. In the case of the demand for long distance telephone service, unquestionably the most important factors stimulating growth have been increased convenience, reliability, speed of service, and quality of speech reproduction.

Our chief objective, of course, in providing more circuits of adequate transmission efficiency, has been to cut to a minimum the delay which the calling subscriber experiences before reaching his called party, thus increasing the value of the service and, incidentally, inducing him to use more of it—a result which in turn makes additional circuits necessary. This to-and-fro process has, of course, been influenced by periodic reductions in rates as improved facilities and a larger density of traffic have permitted. Nor should I fail to mention that one of the most important factors in this "chain reaction" has involved the development of superior operating techniques and more direct circuit routings which have been of assistance in enabling the operators to reach distant points quickly.

The Development of the General Toll Switching Plan

THESE considerations lead me to a discussion of what we call a general toll switching plan. It is quite apparent that when the art had reached a point where seconds counted in

completing calls, very careful study indeed had to be given to the question of clipping unnecessary seconds from our operating times. Such a study had to be nationwide, giving attention to the calls that pass between far corners of the country as well as to those that flow over the heavy trade routes.

At the same time, it is equally obvious that the solution could not lie in direct circuits from each exchange to every other exchange. Such an arrangement would be too profligate and unwieldy to be commercial. On the other hand, due weight must be given to the fact that the toll business has shown a more rapid growth in the longer lengths of haul than for the shorter hauls. For example, during an interval in which the messages on hauls up to 250 miles doubled, the messages on hauls from 250 to 1,000 miles increased five times, and those over 1,000 miles increased more than ten times.

All measures of the quality of service—speed, accuracy, and transmission—show that the difficulty of giving satisfactory service increases rapidly with the number of intermediate switches. The general toll switching plan, therefore, involves the layout of toll circuits in such manner as to limit as much as practicable the number of switches required to connect any two telephones, and also the establishment of standards of design and construction giving satisfactory transmission over any route thus established.

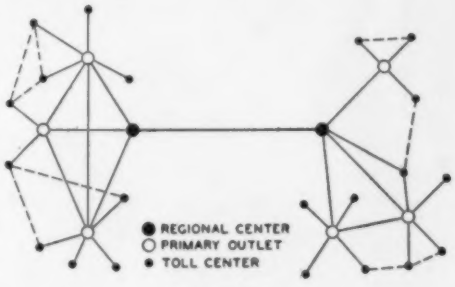


FIGURE 4

Schematic illustration of the general toll switching plan, showing the interconnection of important switching offices throughout the Bell System. Solid lines represent fundamental routes; dashed lines, supplementary direct circuit groups

THE general features of the plan will be understood by reference to Figure 4. It shows the application of the plan to a limited operating area such, for example, as a region of the United States. Within the area are selected a small number of important switching points designated as "primary outlets." Each toll center is connected directly to at least one of these outlets and all primary outlets within the area are directly interconnected. This makes possible the interconnection of any two toll centers within the area with a maximum of two switches; and, within the part of the area served by one primary outlet, with a maximum of one intermediate switch.

The primary outlets have been selected after a careful study of the switching and operating conditions and the probable development of toll traffic within the various areas with a view to obtaining the minimum number of primary outlets capable of handling the traffic economically. The routings provided by the plan are supplemented by direct circuits, or by other routings where the amount of business justifies such additional cir-

FIGURE 5

Regional centers and primary outlets of the general toll switching plan in the United States and Eastern Canada

cuits, as indicated by the dashed lines in the drawing. In general, the requirement is made that these supplementary routes shall be at least as satisfactory, as regards both number of switches and transmission, as the routes provided by the fundamental switching plan. However, when the supplementary routes are used only as alternates to a primary routing, they may be somewhat less satisfactory in these respects.

The nationwide array of primary outlets is shown in Figure 5. We have found it practicable to take care of switching for the 2,500 toll centers of the United States and eastern Canada by the establishment of approximately 150 of these as primary outlets.

To facilitate the handling of longer haul business, eight of the largest cities have been designated as regional centers. These are New York, Chicago, St. Louis, Atlanta, Dallas, Denver, San Francisco, and Los Angeles. Each primary outlet is connected with at least one regional center and with as many more as practicable. With few exceptions, each regional center is directly connected to every other regional center in the country. However, there are many more direct routes than this statement would imply. By this means, any one of the primary outlets, which are the 150 most important switching centers in the country, can be connected to any other primary outlet in the country with a maximum of two switches, and within the area served by a regional center with a maximum of one intermediate switch. As an illustration of the con-

centration of switching which results, New York serves as regional center for the entire northeastern section of the United States and eastern Canada.

Figure 6 represents direct circuits radiating from Chicago. You will note that several important cities in the Mountain States other than Denver have direct lines to Chicago. Furthermore, there are cities in the South which can be reached without a switch at Atlanta.

One possible ultimate development would be the increasing connection of primary outlets to a single regional center, so that ultimately only one regional center would be necessary. If this were to take place, the regional center would undoubtedly be Chicago. The illustration is interesting as showing the extent to which the primary outlets already are connected directly with Chicago, over one-half of them having such direct connection.

Future growth will doubtless lead to an increase in the number of toll centers connected directly to a regional center. By this process there would be a continued growth in the number of toll centers which can be interconnected with a maximum of two intermediate switches.

LOOKING to the future, an increasing amount of the outgoing traffic will be handled by operators in the local central offices, reaching the toll line over toll tandem trunks. It is evident, however, that the ultimate solution of the problem will involve the use of machine methods for the selection of the toll line by the operators, as is now done in certain segregated toll tandem systems.

The entire trend of recent years is thus to decrease the differences between the handling of exchange messages and of toll messages. At the

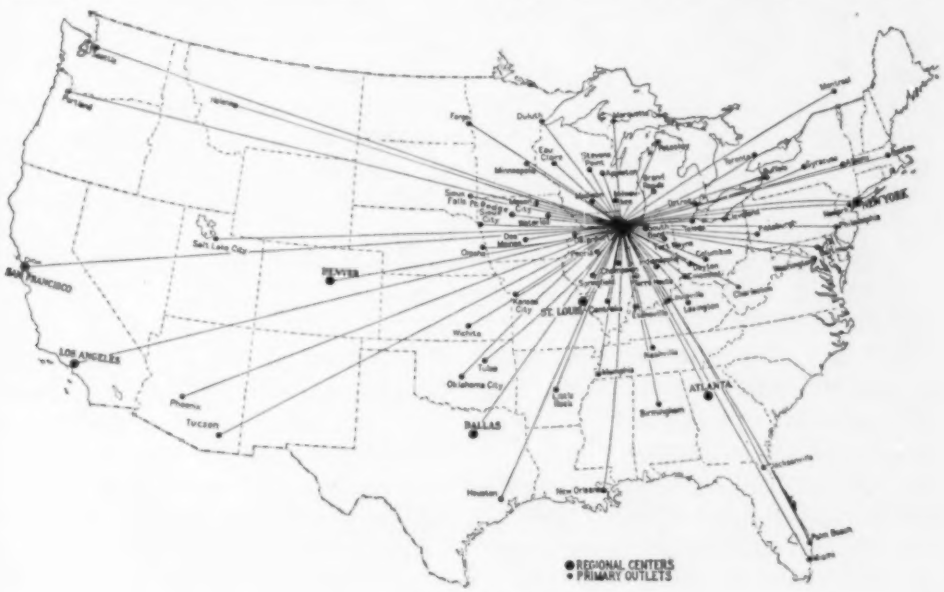


FIGURE 6

Direct circuits radiating from Chicago

present time more than 90 per cent of the toll messages are completed while the subscriber remains at the telephone, with speeds of completion only slightly slower than those of exchange messages. Transmission standards, while naturally somewhat better for the shorter distances involved in exchange messages, are, nevertheless, rapidly becoming very comparable. The present view of trends for the future is for continuation of this process, perhaps even to the use of similar types of machine equipment at central offices for switching the various classes of messages.

Transcontinental Routes and the Development of Carrier Systems

IN order to justify the reference to transcontinental telephony which is contained in the title of this talk, I must return to it from time to time. I do so again at this point to mention that the original line with three circuits has now become four routes with about 170 circuits. You have doubtless surmised, as a result of the discussion of the toll switching plan, that the number of coast-to-coast circuits must have mounted steadily and that they probably were directed over divers routes. This, precisely, is the case.

Following the historical sequence, second in order of time was a line running west from Dallas (1923) and terminating in Los Angeles. This carries 31 circuits, 15 voice frequency and 16 carrier. Next there followed the so-called northern transcontinental line, which runs west from Minneapolis and terminates at Seattle, and which has six voice frequency and 16 carrier frequency circuits. Finally, there was completed about three years ago a fourth route, which runs west through Oklahoma City and, passing through Albuquerque, terminates in Los Angeles. It carries eight voice frequency and 69 carrier frequency circuits. You will see, therefore, that carrier systems predominate today in supplying the very long haul facilities.

I might add that, whereas earlier carrier systems which we developed some twenty years ago were designed to provide three and four carrier circuits per pair of wires, the latest systems to be introduced—there is a type J for open wire and a type K for cable—are twelve-channel affairs, while the coaxial cable which is now undergoing installation for commercial service will provide hundreds of telephone circuits on a single pair of conductors. Of course, these systems are and will be increasingly used on routes other than transcontinental. At the present time we have a total of nearly a million miles of carrier circuits, and so far as the telephone user is concerned, and even so far as our own traffic people are concerned, there is no distinguishable difference between a voice frequency and a carrier circuit.

EARLIER in my talk I mentioned the electric wave filter invented by Campbell. It is, of course, in connection with carrier systems that the filter finds its most important application in telephony. I shall assume that you are all familiar with its operation and so shall merely state in passing that it provides a most elegant scheme for separating at the point of reception

the various messages which a carrier system handles simultaneously. You will recall that it was an outgrowth of the mathematically deduced characteristics of the loaded line. Thus, we stumble upon another interesting relationship. What we put out at one door comes around through another; for while we have dispensed quite generally with loading coils on long lines in order to adapt them to carrier operation, carrier itself would not be feasible were it not for the wave filter which grew out of the loaded line.

From carrier systems it is natural to digress for a moment to other high frequency facilities. Chief among these are the radio telephone channels, some overseas and some for ship-to-shore and harbor operation. The topic of radio telephony is pertinent to our present discussion for quite another reason, however. Some of you may recall that it was less than a year after the first transcontinental line was opened in 1915 that we succeeded in transmitting speech by radio across the Atlantic Ocean. Words emanating from the Arlington antenna at Washington were received at the Eiffel Tower in Paris, use of both structures having been granted to us for the purposes of the experiment. The vacuum tube which brought success to the transcontinental program began early to show its versatility.

However, our transatlantic equipment of 1915 was crude in the extreme compared to what proved necessary to offer a commercial overseas service. Although a one-way demonstration from New York to London was given in 1923, it was not until 1927 that the British Post Office, which operates the telephone system in Great Britain, countered with a transmitter to send from east to west. Since that time, overseas channels have bobbed up with surprising rapidity all around the earth, so that today some 93 per cent of all the telephones in the world can be connected, one to another. From the United States we can telephone to seventy-four other nations—or can when peace-time conditions prevail. One of the stunts performed a while ago was to talk from one office in New York City to a nearby office by a telephone circuit which circled the globe.

Each Success Has Inspired New Efforts in Laboratory and Field

I MUST now undertake to conclude this discussion of what grew out of one particular kernel, if you will allow me to refer to a circuit some 3,000 miles in length as a kernel. Perhaps it might better be compared to one of those long chain molecules which the chemists are employing these days with surprising results. Time forbids more than a mere mention of numerous other essential devices which are playing their part in this broad subject of present-day telephone transmission. Such things as phase correctors, automatic gain control of repeaters, volume compressors and expanders, echo suppressors, etc., ought really to receive more comment than I can give them, to say nothing of various refinements in operating techniques which have been of great importance. However, I trust that I have succeeded in giving you at least a glimpse of how some of the chapters

of this technological romance have unfolded.

Thirty years ago the problems of long distance telephony and particularly the problems of transcontinental telephony were very concrete transmission problems. Because the greater obviously included all the lesser, it was taken for granted that a satisfactory solution of transcontinental telephony would have far reaching effect on all long distance telephony. For the most part we thought of the effect in terms of transmission rather than such things as speed of service or toll switching plans.

IT would be easy to claim too much for the descendants of the physical things that were first utilized commercially in the transcontinental circuits of 1914–15. At the same time, it is largely because of these descendants, developed to do a multitude of things, that we have present-day national and international telephone service; that the distant party is obtained while the calling party is still at the telephone; that we have a toll switching plan and can contemplate a better one; and that we can talk about circuits which girdle the globe or operating methods which tend to wipe out existing differences between local and long distance service.

None of us who were in the game from the start, thirty years ago, were bold enough to envisage what is commonplace today. But each success as it came along inspired new effort both in laboratory and field, and by a process of probing into Nature, inductively in the laboratory and deductively by means of mathematics, and with constant study of the operating problems which our traffic people have encountered, we have, I believe, made creditable progress. I want to impress upon you that close coöperation was necessary every foot of the way. In bringing the fruits of science to the service of a vast public in a manner such as the telephone accomplishes, there has been no room for the dictatorial method, except of course as Nature does the dictating. We must try at all times to plead our case intelligently before Nature, and sympathetically before the public. As a matter of fact, the public and its reactions are as much a part of Nature as the electrons which carry our messages, and transgression of its laws of reaction would have been about as inimical to success as would a failure to understand the laws of electromagnetism.

In its journey covering a quarter of a century, telephony has, as you have seen, crossed several thresholds —but, at this, the journey may be in its early stages. If progress continues at the present rate for another twenty-five years, you will have to grant two evenings to the speaker whom you select to deliver your Steinmetz lecture in 1964.

IT has been my good fortune to have had a part in a great adventure, some of whose principal features I have attempted to sketch out for you. I would be less than honest and far less than generous, however, if I allowed any of you to depart with a false impression of my personal contributions. The achievements embody the contributions of many men, my associates (some of whom I do not even know), working through the years as a team of which I have been a member.

OUR EXHIBITS AT TWO FAIRS

More than Thirteen Million Visitors Enjoyed the Bell System's Hospitality, and Learned about It and Its Services, at the New York Fair and the San Francisco Exposition

I. AT THE NEW YORK WORLD'S FAIR

By THOMAS W. WILLIAMS

"Four hundred telephone men and women entertain eight million visitors." That is how a headline for the Bell System Exhibit at the New York World's Fair might be written. The four hundred telephone men and women and the eight million visitors of the headline are merely facts told in volume of people. The story of what was done in the name of the Bell System, and how it was received by those who came as our guests, is in the word *entertain*.

Perhaps it would be well to depart for a moment from headline technique and give exact data. The actual attendance at our Exhibit was 7,878,000, which was thirty per cent of the total paid admissions to the grounds, numbering 26,409,000. The average daily attendance was 42,600, with the maximum on a single day of 130,000 and five days having 100,000 or more. The length of time the average visitor stayed in the Exhibit was 22 minutes, and a fourth of them were there for over 30 minutes. In view of the magnitude of the Fair and the competition from other exhibits and attractions, these figures of attendance and length of visit are significant. They were influenced by three factors: the type of exhibits, the arrangement and housing of them, and the personnel who operated them.

The Exhibit was planned, as told by John Mills, of the Bell Telephone Laboratories, in the October, 1938, Quarterly, according to two criteria. These were: (1) the desirability of attracting participation by visitors in something of personal interest to themselves; and, (2) providing exhibits of scientific novelty comprehensible to the general public. The exhibits selected were the Demonstration Telephone Call, the Voder, two Hearing Tests, Audition, two Voice Mirrors, a Model Dial Unit, and ten displays in the Hall of Pioneers portraying a scientific presentation of development in the telephone art. Not only was participation in nearly all the exhibits easy, but they covered a wide range of human-interest subjects and they were comprehensible to the general public.

The building, from the shining gold Genius of Electricity atop its towered portion to the mosaics and symbolical panels at the entrances, its sculptures and its beautiful landscaping, has been described as among the finest on the grounds. Its interior, true in proportion and design, harmonious in decoration, and artistic in the staging of exhibits, had an atmosphere of dignity and welcome.

The operation of the Exhibit was the responsibility of the New York Telephone Company, and the personnel, of approximately 400 people, was recruited largely from its ranks.

Having, then, exhibits which were inviting because of their scientific novelty and personal benefit, and a building of both character and beauty, there remained an important complement—the manner of the personnel. Naturalness was, obviously, the desired characteristic; and in order to achieve it our people at all times regarded the visitors as their personal guests, to whom should be extended the same friendliness shown to guests in the home.

The Story of Our Exhibit—Told by Visitors

THE figures of daily and total attendance have only quantitative value. They do not answer the important question: How was the Exhibit received by our visitors and how did they and the Bell System benefit from it?

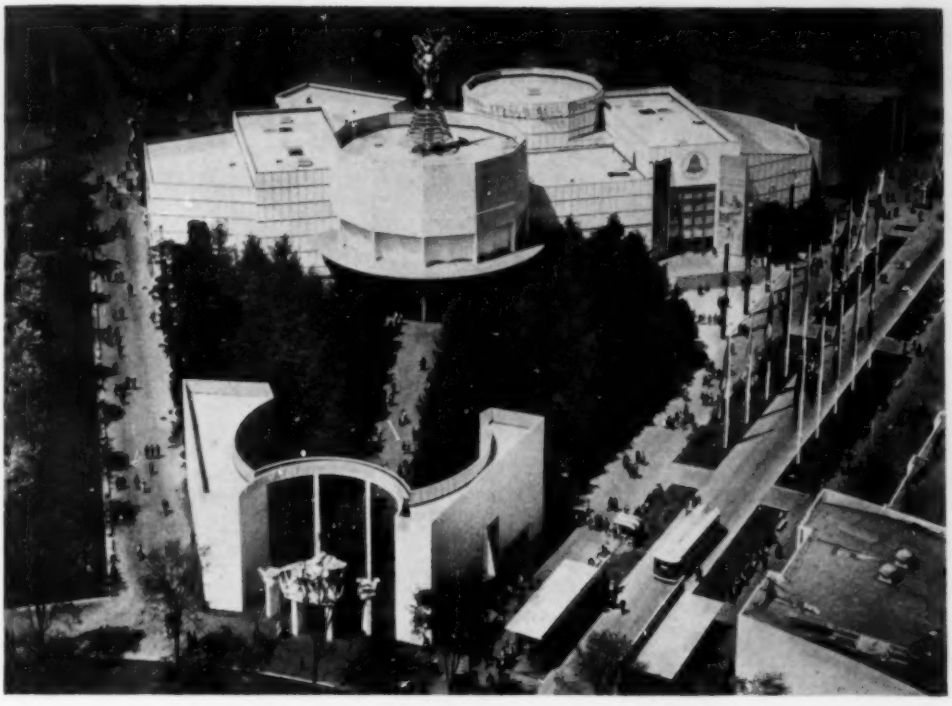
The usual way of answering the first part of that question would be to describe the color and human interest of crowds when they are on the hunt for pleasure and scientific novelty. In other words, to write of the Exhibit and its crowds objectively. There is perhaps a better way, and that is to treat the matter subjectively.

During the course of the Fair, visitors by the hundreds voluntarily expressed to members of the operating personnel, by word of mouth and by letter, their impressions of the Exhibit. The manner of calling these visitors as our witnesses will be to quote just a few of their typical comments as they relate to each part of the Exhibit.

The Long Distance Demonstration

IN the six months of the Fair, more than 540,000 people filed applications for demonstration calls, and 30,000 were successful. It is estimated that 1,500,000 listened in. These calls were made to points all over the Nation. Where a call was to a telephone served by one of the country's 6,000 non-Bell companies, the connection was completed through the courtesy of the telephone company operating in that area, under arrangements endorsed by the United States Independent Telephone Association. To those participating, either by winning a call or by listening in, these conversations were endlessly amusing. The startled ejaculations of the person called on being notified of the identity of the call, and the warning by the person calling—emphasizing the operator's formal notice—that because people were listening in, the conversation should not divulge family secrets, were the refrain of almost every call.

At times hilariously funny, at times merely hum-drum, at times revealing the finer instincts in human nature, and containing always the element of



THE BELL SYSTEM BUILDING

Taken from high up on the "Trylon," this picture gives in perspective a view of the structure in which thousands of visitors each day were welcomed and entertained

the unknown, these calls never failed to attract as a unique portrayal of human behaviorism. From the opening day in April to the close in October, applicants were always in line, and the 270 listening-in receivers were constantly in use, so that the crowd made the show its own and had a grand time doing it. There were comments by the score showing keen appreciation of the speed and quality of the service. Of course, the conversations brought out countless amusing incidents. To select a few of them would be easy, but to do them justice would require the talent of O. Henry.

There was one unique incident. Early in the summer a letter was received from a young man in a distant state saying he had talked with his fiancée from our Exhibit. He wrote that, emboldened by the thrill of the call and by recent employment, he had, during the conversation, proposed marriage, and the girl's answer had been *yes*. He believed his cup of joy would be completely filled and our publicity greatly enhanced by a marriage ceremony at the demonstration call exhibit in our building, for which he offered himself and fiancée as principals—for a consideration. The reply to his letter stated why his plan

SOME OF THE FOUR HUNDRED

This group is representative of the entire Exhibit staff, whose courteous and friendly attitude created good will for Bell System men and women everywhere

could not be accepted, and concluded with best wishes for a happily married life. Then, just prior to the close of the Fair, the writer received an invitation to the wedding.

BUT we were to call the witnesses, and here they are:—

"My biggest thrill at the Fair was when I heard a little girl speaking to her mother in St. Louis."

From a young woman: "This is the most interesting exhibit at the Fair. The long distance demonstration is simply wonderful."

A manufacturer said he was much impressed with the long distance demonstration. He added that the Exhibit not only displayed the speed with which calls are handled and the national scope of the service but also demonstrated making or receiving a long distance call, the thrill of talking across the continent, and the thousand and one little things that go to make up the daily conversation of the nation.

Elderly man: "I heard a conversation clear across the United States. What a thrill!"

A man said he had heard so much about the toll call demonstration, he came into the Exhibit just to see it. He commented on the speed with which connections are established, both here and from regular telephones.

The Voder Amazes and Amuses

DURING the last two centuries, scientists have been endeavoring to produce speech synthetically. It remained for Bell System research specialists to be the first successfully to achieve a complete result. If a visitor entered the Voder room and joined the listeners, he saw the Voder being operated and heard what could be done with it. But if he stood at

a point from which he could hear it and at the same time look into the faces of the listeners, he saw impressively the effect it had upon them. That they were hearing something of startling scientific import and profound human interest was obvious from the expressions on their faces, for uniformly they listened in rapt and appreciative attention.

The dialogue between the man at the microphone and the girl at the Voder proved a happy combination of scientific explanation and almost casual conversation. Then, at the point in the program where the visitors were invited to suggest words for the Voder to say, the crowd took the show over. Oshkosh, antiphlogistine, Tuscaloosa, antidisestablishmentarianism, Popocatapetl, onomatopoetic, Saskatchewan, the spelling of Mississippi—these were some of the favorites. And always at the lilt of the last two syllables of Minnehaha the crowd roared.

It is estimated that the number of visitors to the Voder room exceeded 5,000,000. Here is what the witnesses say:—

"That machine is a wonderful accomplishment, and demonstrates the skill of telephone engineers in handling problems of speech."

Man from U. S. Patent Office: Stated he had visited the Voder demonstration several times and it is the most remarkable of anything he had seen at the Fair.

"Is is true that there really is no phonograph record? My, it's amazing!"

Elderly man: "The miracles, as the Bible describes them, are really true, for here in this room we are witnessing a modern miracle. The wonders of God transmitted through man's mind are truly being demonstrated here."

"I am tired of the regular Voder demonstration. I have heard it 19 times and I come in now only to hear the Voder try new words. I visit your Exhibit on every trip to the Fair."

ACROSS THE CONTINENT

The long distance demonstration was spectacular to watch as well as fun to listen to

A man said that the Voder is a wonderful example of the advancement the telephone industry has made in the technical research of sound and speech.

"The Voder is just marvelous and so is the girl who is operating it."

Woman Science Teacher: Said that, in her opinion, the Voder is the nearest approach to a human function in science.

Professor of Oriental Languages: Said he was impressed by the mechanical and electrical marvels of the machine. He had an idea of the difficulties which had to be surmounted because of his experience in teaching Arabic and other languages by phonetics. He added that he intended to put our Exhibit on the "must" list for his associates on the faculty.

Hearing Tests Were Very Popular

AMONG all the exhibits at the Fair the hearing tests ranked high in novel appeal and personal benefit. That they were so considered is indicated by the fact that the tests given to visitors totaled 1,700,000. As visitors completed the tones test, girl attend-

ants entered check marks on completed test cards showing sex, color, and approximate age of the visitor. Recordak photographs were then made of the test cards. It is the first time information of this kind has been available in such volume, and its value to telephone engineering and the whole field of human hearing is substantial.

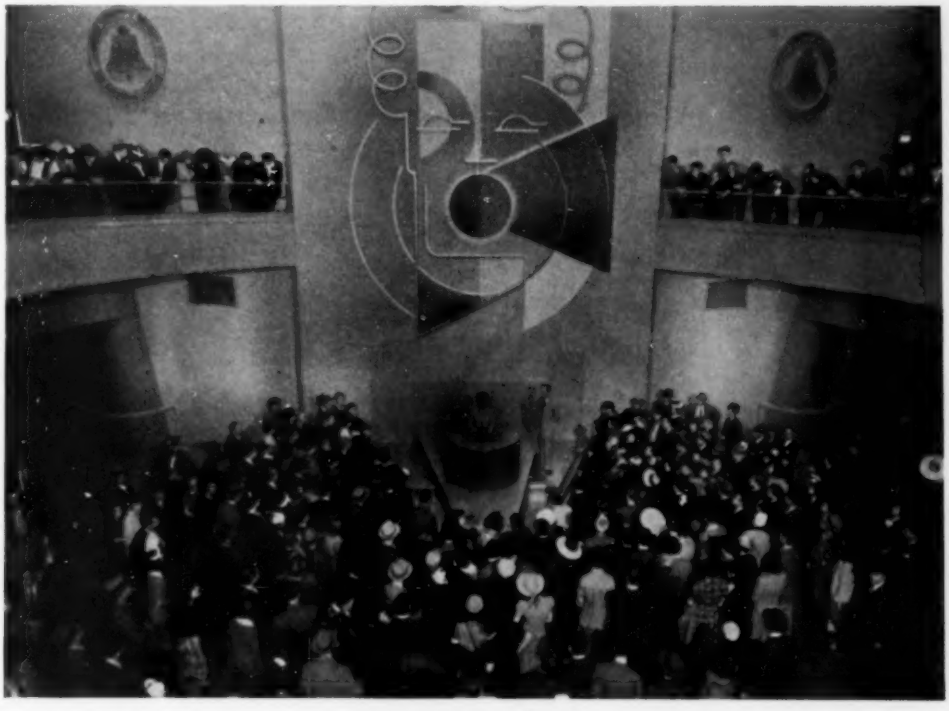
THE witnesses say:—

Man: Said the Bell System is doing mankind a real service in providing hearing tests. He added he was much impressed by the girls employed at the Exhibit.

"My left ear is better than my right ear. I am certainly surprised to know that."

Woman: Said she had taken a hearing test a month ago and her hearing was slightly impaired. Since then she had gone to an ear doctor for treatment, and this test now showed her hearing perfectly normal.

"I am a railroad engineer and always thought my hearing was impaired by the wind when I ride with my head out of the locomotive window. It is the surprise of my life to find my hearing normal."



THE VODER FASCINATES THE CROWDS

The manipulative skill of the operator's fingers makes the Voder's voice almost too good to be true

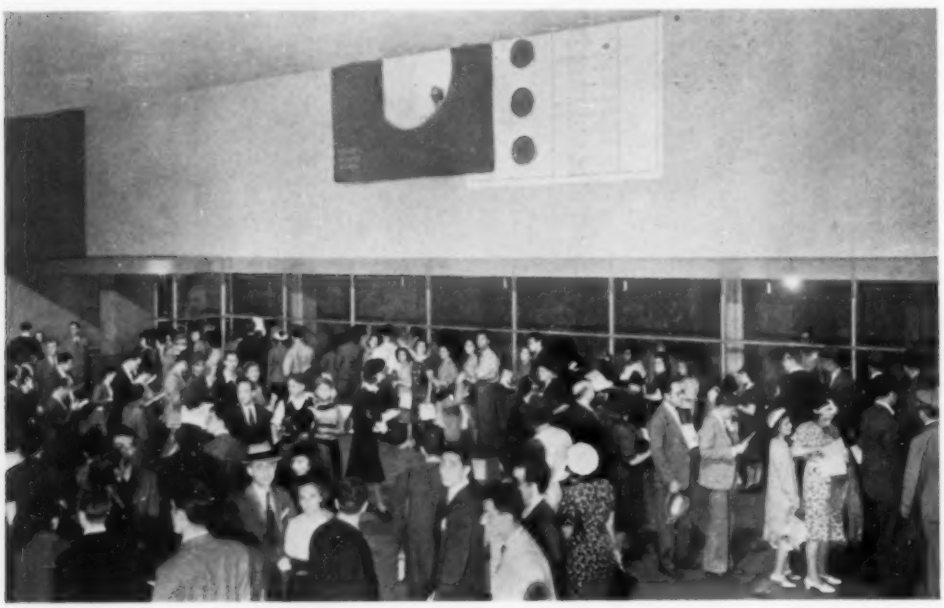
Man: Said he failed to hear the high frequencies in the tones test and this had convinced his wife he did not and could not hear the squeak in the family car. He added this argument had been going on for some time.

—*As Others Heard Them*

IN attempting to describe our exhibits, one is conscious of the limitations of space. This is particularly true of Audition, for it would be easy to write of it at great length. The attractive garden scene, the informal social conversation between a group of visitors and an Exhibit man directing the conversation, the substitution of mannequins for the visitors, and the high-fidelity reproduction of the conversation made a diverting show which attracted audiences of lively interest.

At the opening of the Fair the public seemed to appraise Audition as something of a stunt. But almost immediately it came to be regarded as an entertaining event by everyone, and as an experience of direct personal benefit by many of those who participated.

Again and again individuals who had been unsuccessful in winning a chance to participate requested that they be permitted to try it. The requests came from teachers, clergymen, vocal students, lawyers, doctors, from those with impediments of speech, from those who considered the opportunity of hearing such an accurate recording of their voices as helpful in their occupations, and from those who regarded Audition as a means to better habits of speech.



LINING UP—

—for hearing tests, which were of interest to hundreds of thousands

AUDITION! HEARING THEMSELVES AS OTHERS HEARD THEM

The dummies on the stage appear to be repeating the conversation just completed by a group now seated at the foot of the garden

On rare occasions, instead of a group of five visitors, one person gifted in the art of pleasing conversation would be given an audition alone by an Exhibit man. These diversions were always entertaining.

Of course, the purpose of Audition was to give people an opportunity to hear how their voices sound in normal conversation. This was pointed out to each group in the short preparation period before its audition and it was urged that the replies to the interlocutor's questions include at least three or four sentences. But there were some groups in which all five people responded in single words whenever possible; the shorter the better, they seemed to think. In such cases the most successful Exhibit man, bombarded by these bullets of brevity, could get nothing but grief for himself and zero for the audience. Fortunately, they were few in number. In fact, a survey developed that, judged by rather severe standards of measurement, three-fourths of the shows could be classified as excellent or good and most of the others as fair.

OVER 100,000 participated in Audition, and it is estimated that nearly 6,000,000 stopped to watch it. The witnesses say:—

"I have been troubled by stammering, and my voice teacher suggested that I visit your audition exhibit. I have heard myself talk and it was the thrill of my life."

Man from Northern Canada: "Up home, when anyone says he is going to the World's Fair he is bound to be told, 'Don't forget to go on the stage where you hear your voice in the Telephone Exhibit—it is the best thing at the Fair.'"

Man from England: Said he was told about Audition by a friend who met him at the boat that morning. He said we have "a grand show, just full of human kindness."

Woman: "As a cooking teacher, I address large groups of women and I am interested in knowing how I sound to them. Your audition has been the high spot of the Fair to me."

Woman from South Africa: "I am in the States for a visit and have seen quite a bit, but an opportunity to hear myself speak was not anticipated. All the wonders I have seen and the things I have done since coming are overshadowed by this experience."

Woman University Teacher: "This equipment should be made available for every teacher of speech in the country. One audition has far more value to a student of speech than hours of reading before a critical audience."

An Assistant Attorney General: Said he came to our Exhibit especially to hear his voice, and used the same tone and volume he ordinarily uses in a courtroom. After the reproduction he said, "I always knew I could fill a room with my voice but I found out today how easy it is to empty one."

Voice Mirrors Have Wide Appeal

WHEREVER used, this exhibit has wide popular appeal. Voice mirrors were provided at two locations in the building, and it is estimated that 1,100,000 talked into them and 1,500,000 listened in but did not talk. Comments are:—

Elderly blind man from Colorado: "My boy said they call this the voice mirror, which in my case is well named. For the first time in 25 years I actually did see, you might say. My voice was reflected in my ears, which both see and hear for me."

"I like the voice mirror because I'm a teacher and now I know how I sound to my students."

Man from Colombia, South America: Said he had talked with people in South America who visited the Fair and had been advised to visit the Bell System Exhibit. His friends had told him particularly about the voice mirror.

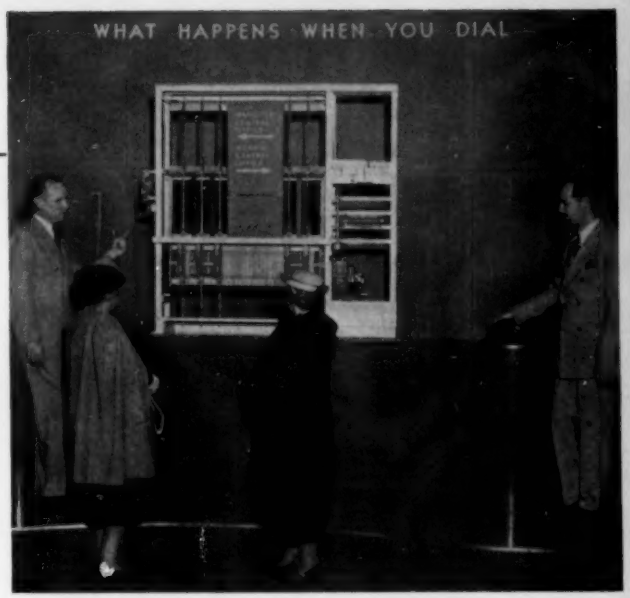
Middle Aged Woman: "It is indeed wonderful to talk into a telephone and have your own voice come back to you. It's a great age to be living in."

Elderly Woman: "I want to hear what I sound like on this contraption"; and, after trying it, "I think I have a real nice voice for an old lady."

The Model Dial Demonstration

THIS exhibit was a small assembly of panel-type dial equipment about five feet wide and four feet high. The demonstration, given by one of the Exhibit men, consisted of dialing a call from a telephone in an originating central office to one in a distant office.

The demonstration of dial operation helped many to a clearer conception of how the service is provided



The apparatus was equipped with the five essential selectors, rotary and sequence switches, and message register. Demonstrations went on continuously. A dozen listeners was a small group and the exception, with the number ranging occasionally up to well over a hundred, the capacity of the available space. The close attention of the listeners indicated their genuine interest in an opportunity to see What Happens When You Dial—which was the designation on the wall above the exhibit.

At the conclusion of each demonstration, visitors were invited to ask questions. They were always curious about the electrical registration of calls, toll charges, the operation of the busy test, those involving mechanical features, and a wide range of telephone subjects. These discussions were of the most friendly sort and both questioners and listeners seemed to enjoy them. It is estimated that 900,000 witnessed the demonstration. And here is what some of them say:—

"I have frequently been skeptical concerning your accuracy in billing additional local messages, but now I believe your system of recording and compiling local message charges is excellent."

"We have dial service at home and I have always wondered how it works. I was interested in the dial demonstration but I still think it quite complicated."

"This is the most enlightening and enjoyable scientific display I have ever seen. It acquaints the public in an understandable manner with the dial system. The average individual should be able to appreciate the vast improvement that the dial system brings."

"How interesting! Now for the first time I feel that I understand what happens when I dial!"

"The maze of equipment in a dial office has always puzzled me. You have given me the simplest and clearest explanation I have ever heard."

Man: Said he and his wife enjoyed the dial demonstration greatly. He added he never gave much consideration before to what actually happened when he dialed but just took it for granted.

Man: Said he had always attributed his high bills to the fact that he was charged for "busy" calls. He added he was glad that he had stopped at the dial demonstration and learned that his register does not operate on "busy" calls.

The Hall of Pioneers

THE exhibits in the Hall of Pioneers, in addition to a large voice mirror,

were chiefly displays of telephone apparatus, showing the improvements that have been made in cables, coils, central office equipment, and telephones. The oscilloscope, which made visitors' voice waves visible when they spoke into it, was always a source of amazement. Men were available to explain the exhibits to visitors and many comments of appreciation were received.

Pioneer Lounge, the gathering place for telephone people from all parts of the System, was well patronized, the registrants numbering nearly 4,500.

The comments given thus far relate to specific exhibits. Many others were either of general nature or referred to the personnel. Here are a few of them:—

"This seems to be the only exhibit at the Fair visitors can take part in."

"As a stockholder, I am proud of your Exhibit and I'm glad that a part of my investment is used to create a better understanding with people."

"The shrubbery and trees about your building are beautiful. I just had to take a photo of it."

Two visitors from England: Said they had been advised by friends who had returned to England to visit the Bell System Exhibit as a "must" item on their trip.

Man: Asked what school of diction had been attended by the Exhibit staff. Said he had never heard better diction in any group than he had from the men and women in this Exhibit.

Man: "So all these girls are telephone operators? And to think how sassy I have been to them over the telephone."

THE exhibits contained many complex circuits and much intricate apparatus, and it is to the credit of the plant maintenance group that they were so effectively conditioned that there were no serious failures and the few interruptions were of minor character.

It should be said that the operating force—the supervisory staff, instructors, men, girls, pages, guards, porters, all of them—at all times were conscious of the fact that courtesy and friendliness on their part would be accepted by the public as recognized qualities of the great organization they represented. And they so maintained this standard that not only were there many comments of appreciation for their treatment of visitors but also regarding the attitude and relationship of the personnel toward each other.

TO repeat part of a question raised earlier in the text: How did the visitors and the Bell System benefit by the Exhibit? Well, the visitors, by the crowds in which they came, by the enthusiasm with which they participated, and by their comments, some of which have been quoted, have spoken for themselves.

And how did the System benefit? In many ways. In a building of inviting dignity, people found exhibits which were interesting, entertaining, and in many cases personally helpful. Most of the things they saw and did were indicative of the part research plays in providing present-day telephone service, and all of them were

"PEOPLE ARE LISTENING IN"

Receivers bring the demonstration long distance calls to listeners on the ground floor, while visitors on the balcony watch the progress of the calls across the great map and even those on the escalator try not to miss anything

expressive of the wide scope of the System's undertakings. Visitors took away with them an impression of the courteous treatment which is representative of the attitude of telephone people everywhere toward the public.

Not least valuable to the System was the knowledge of the speed, extent, clarity, and convenience of our long distance service gained at first hand by the 30,000 who made demonstration calls—and the equal number who received them—and by the 1,500,000 listeners who partook vicariously of the same experience. The opportunity to give such large numbers of people, from all sections of the country, direct and personal acquaintance with those features of the service occurs only at world's fairs, and is, indeed, one of the principal advantages of System participation in these expositions.

Eight million people came to the Bell System Exhibit. However long they stayed, however many of the exhibits they saw or heard or took part in, they left, we may confidently believe, not only with an increased knowledge of the System's services but with a better appreciation of its methods and its aims as they were typified by the building, the individual exhibits, and the personnel.

II. AT THE GOLDEN GATE EXPOSITION

By LAURENCE N. ROBERTS

On February 18, 1939, the Bell System Exhibit at the Golden Gate International Exposition was launched with high hopes. On October 29, 1939, when the curtain was rung down at the close of the Exposition, those hopes had been proved to be well justified.

Throughout the year it became increasingly evident that the Exhibit had a wide popular appeal. Indeed, it is easy now, looking back, to see that in the conception of the several demonstrations the probable reaction of the public was accurately gauged. We feel that great credit is due to John Mills, of the Bell Telephone Laboratories, and those associated with him in designing the Exhibit, for their clear preconception of this situation.

The following letter from a visitor, which expresses this thought, is, we believe, typical of the feeling of a majority of persons who visited our exhibit:

"Since the day the Fair opened, I have visited the Island twelve times, and on each occasion I make it a point to spend some time at your exceptional exhibit. The American Telephone and Telegraph Company is to be congratulated on presenting the smartest exhibit at Treasure Island. Whoever presented the idea deserves a world of credit, for from the public relations standpoint, it couldn't be better. I have no favor to ask; I just feel like remarking on an excellent job well done."

From the outset, the public rated the Bell System Exhibit one of the most attractive and interesting at the Exposition. Very rarely did people enter into a discussion of what to see on Treasure Island without putting the telephone exhibit on their "must see" list. When people were overheard discussing what they had seen at the Exposition, they invariably spoke of our Exhibit as an outstanding attraction. Also, when one stood at the exit of the Exhibit listening to the comments of people as they were leaving, one continually overheard such comments as, "Isn't this a grand exhibit!," and "This is certainly an interesting exhibit."

The attendance figures graphically illustrate the popularity of the Exhibit. Of the 10,496,000 persons who paid admission to the Exposition, approximately 5,334,000, or 50.8 per cent, visited the Bell Telephone System Exhibit. The average length of time visitors remained was about 30 minutes.

The popularity of our Exhibit was not, we believe, traceable to any particular demonstration. Each showed its value in attracting people. This is borne out by the following analysis of results obtained by the various demonstrations.

The Long Distance Demonstrations

The demonstration of long distance telephone calls undoubtedly caused more repeat visits than any of our

EXTERIOR OF THE BELL SYSTEM EXHIBIT

It was housed in its own structure within the Palace of Electricity

other demonstrations. Many people who were frequent visitors to the Exposition made it a point to apply for a demonstration call on every trip to the island. Some persons spent an entire day in our Exhibit.

During the period of the Exposition, nearly 546,000 visitors made application for demonstration long distance calls. Of these, more than 37,000 were given the opportunity to place calls. Approximately 82 per cent were completed. Of those not completed, "don't answer" accounted for 75 per cent.

Calls were handled to places in every state of the Union and the District of Columbia. In cases where calls were to points served by non-Bell telephone companies, connections were completed by the companies operating in those areas, under arrangements endorsed by the United States Independent Telephone Association.

The length of time people listened in on demonstration calls varied from a few moments to several hours. A majority of the receivers were in use all day. As a matter of fact, the occasional inability of people to find available one of the 125 receivers added to the popular interest in the demonstration and caused many return visits.

However, participation was not requisite to enjoyment. Many visitors who did not apply for a long distance call or listen in expressed themselves as being pleased with this demonstration. Because of the attractive appearance of the map, with its brilliant chain of lights indicating the path of the call, the illuminated sign which indicated the city and state to which the call was going, and the "thermometers" showing the length of time for each step of the call, crowds of people stood watching the

map for considerable periods of time with evident interest.

Many comments were received from the public, both orally and by letter, expressing their appreciation for this demonstration. The following excerpts are typical of comments received:—

"I have talked by telephone from many states of our nation, but never have had the thrill or enjoyment that the free call gave myself and my wife, who talked to her mother in St. Louis, who was celebrating her 80th birthday."

"From an advertising standpoint I do not suppose I was the best prospect chance might have selected to win one of your free calls; but if the occasion ever arises I am sure that I will use the long distance telephone without hesitation, now that I have experienced the speed and satisfaction which arise from a person-to-person cross country conversation."

"I think your exhibit has brought more happiness to people, by allowing them to call old friends and relatives, than any exhibit on the island or anything your company could do."

A visitor was talking to a friend in the east. The person who was being called said, "Now that the Fair is over

ALWAYS POPULAR

The long distance demonstration was never without applicants for calls nor crowds to watch and listen

The voice mirrors provided entertainment for many, and instruction too

I will miss hearing from you," to which the visitor replied, "But you will still hear from me. I am going to skip a few shows and call you once a month."

"I wish to express my appreciation for an Exposition free call to my son at Princeton, New Jersey, which I won at your exhibit yesterday. Many of us are prone to overlook the courtesy extended by your company in the placing of a transcontinental call without charge, taking the fact for granted, and dismissing the matter from our minds after its completion."

"My only purpose in writing this letter is to let the proper parties know that there is at least one person who realizes the expense attached to this free service, the clarity of the conversation, and the courtesy of the attendants at the booth, and I take this means of making my appreciation known."

Visitors asked many questions about the cost of the calls placed. In each case we presented the questioner with a booklet showing rates from Treasure Island to one or more points in every state. Almost invariably people were surprised at the low cost of telephoning. They usually thought the charge would be two or three times the rate shown in the booklet. Comments made to our people at the Exhibit indicated that many commercial calls have resulted and that many people are beginning to use long distance who had not used it before.

The Voice Mirror Was Popular

THE voice mirror was a very popular demonstration, despite the fact that it has been shown at telephone open houses and at the other recent exhibits of the Bell System. During the busy periods of the day people stood two and three deep waiting for the opportunity to participate. Approximately 900,000 people listened to the reproduction of their voices, and many more than this number participated by listening on [illegible]eceivers to this interesting test. In some cases people returned for repeated demonstrations in an endeavor to correct speech difficulties.

A gentleman complained to the voice mirror receptionist that he had difficulty being heard over the telephone. He said that he had been embarrassed many times by having telephone operators address him as "yes, Ma'am." Observation of his use of the voice mirror telephone disclosed that he spoke very softly and not directly into the telephone. When these faults were called to his attention, the results were greatly improved, much to his delight.

A humorous incident occurred which concerns a foreign gentleman and his family. He said into the voice mirror, "I live at (—) 25th Avenue." When it was repeated back to him, he became very indignant, exclaiming, "I didn't say 55th Avenue. I

Opportunity to test the aculeness of their hearing was welcomed by thousands

said 25th Avenue, 2–5 Avenue." His family tried to explain to him that he did not enunciate clearly, but had difficulty convincing him that the voice he had heard coming back was his own.

Many Tested Their Hearing

THE hearing tests showed a steady increase in popularity from the opening of the Exposition. By April 20, some 70,000 visitors had participated in the hearing test demonstrations, or an average of about 1,100 per day. By the end of the Fair about 383,000 people, or an average of 1,500 per day, had taken the tests. Initially, visitors displayed no preference for a particular test. The demand for the tone test, however, increased from month to month. After August 1st we completed more tone than word tests.

From the start of the Exhibit until about October 1, we photographed all results of the hearing tests by running the cards, which had been filled out by visitors, through a recordak machine. The films were then sent to the Bell Telephone Laboratories for study. Visitors coöperated wholeheartedly in offering their cards for recording, and many were complimentary to the Bell System for this valuable social service.

Many people expressed appreciation for giving them the opportunity of personally determining the quality of their hearing. We received a number of requests for information concerning hearing aids.

One comment received from a visitor is indicative of the value placed on this test by participants. The results showed that the hearing of his left ear was considerably below that of his right ear. He stated that, while in the past he had complained about the quality of telephone service, he now knew the difficulty lay in his own hearing and as a result he planned to use his right ear for hearing over the telephone and not complain about the service any more.

A woman reported to us that on taking the hearing test she found that one of her ears seemed somewhat defective. She immediately went to her physician and had a thorough examination. He found in the apparently defective ear a badly packed wax condition, which, when removed, restored her hearing to normal.

Another comment: "I know my hearing is all right, but I'm an ear specialist in San Francisco and you'd be surprised at the number of people who come to me for advice after taking the test, so I want to find out all about your test."

The Marvelous "Machine That Talks"

THE Voder, like the hearing test demonstration, increased in popularity through word of mouth advertising by visitors. People stood in open-

mouthed wonder listening to the demonstration, and a majority stayed through more than one program. They were enthusiastic in their response during the period when visitors were invited to suggest words for the Voder to say. They viewed the "machine that talks" as a scientific marvel and an exceptionally entertaining program.

We feel that the Voder not only impressed visitors with the value of research work being done in electrical communication by the Bell System, but also played an important part in building good will through the friendly entertaining program. By the end of the fair approximately 2,000,000 people had listened to this demonstration.

On September 13, the National Broadcasting Company made a fifteen-minute broadcast on a Coast-wide hookup of the Voder program from the Exhibit over Station KGO, San Francisco. In addition to the regular Voder program, the announcer described the machine and interviewed a Voder operator, the chief technical man, and the manager of the Exhibit. On September 14, the General Electric short-wave station KGEI re-broadcast the program by electrical transcription to the Hawaiian Islands, the Orient, and Alaska. A few weeks later a visitor who had just arrived from China stated that she had listened to the broadcast in Shanghai and that the

THE VODER SPEAKS—

—and visitors crowd about to wonder at this scientific marvel which creates words at the touch of a girl's finger-tips

A STUDY IN EXPRESSION

The contrast in facial expressions in the "candid camera" pictures above and on the opposite page tells better than words of visitors' reactions to the Voder

Bell System Exhibit was her first objective on arriving at Treasure Island.

When a group of sailors from the British cruiser "Orion" entered the Voder room, the Voder greeted them with "Hello, Orion." The sailors were greatly pleased and one fellow practically exploded with laughter. At the height of his merriment, he slapped his leg and said "Not 'arf bad, not 'arf." They had seen a news reel of the Voder in Bermuda, and as soon as they set foot on Treasure Island they made a bee line to our Exhibit to see "the machine that mykes speech."

Staff Members Realized They Represented the Entire Bell System

IN preparing for the operation of the Exhibit, we realized that while the set-up of the demonstrations insured popularity, good will would be furthered by creating a truly friendly atmosphere. This goal was reached through the whole-hearted efforts of the men and women who formed the personnel of the Exhibit. Helpful, interested, and friendly, these telephone employees were actuated by real loyalty. They sincerely wanted the public to leave our Exhibit with an enhanced appreciation of the spirit of service in the Bell System. We also realized that we were not building good will for the Pacific Telephone and Telegraph Company alone but that we were operating this Exhibit in the interest of the entire Bell System, and that the attitude and conduct of our personnel would affect the opinion of the public in regard to all Bell System people.

All members of the Exhibit personnel, with the exception of the page boys, were selected from the operating forces of the telephone company because they were already imbued with a basic loyalty to the Bell System

and were actuated by the spirit of Bell System service. For the same reason, the pages were either the sons or close relatives of Bell System employees. The young women on the Exhibit staff were chosen not only because of their pleasing appearance but because of indications through their work and through activities outside their jobs that they were interested in people and the activities of their community.

THE development and training of the personnel was based on a program of reviewing with each person the background of the telephone business, and the policy, relationship, aims, and ideals of the Bell System, in order to build a sound foundation upon which to base a feeling of personal responsibility in representing the Bell System to the public. In all our contacts with them we stressed the fact that the public's good will could be earned only as they entered into a real partnership relation for the success of the Exhibit. All readily recognized that they were, in a real sense, giving up their private lives to work in the spotlight of public attention as representatives of all Bell System people.

The response of the personnel to this method of treatment greatly exceeded our expectations. This is indicated by the following letter which was recently received by the manager from one of the young ladies of the Exhibit:

"During your farewell talk the other evening you thanked each of us for our individual work at the Exhibit.

"To be one of those chosen to represent such a great corporation as the Bell System is an honor itself, so I am writing these few lines in sincere appreciation and to thank you for such an opportunity. It will long be remembered.

"The Exhibit being the success it was could result only from close cooperation between employer and employees.

"I am sure that all of the receptionists feel, as I do, that it was a

great pleasure working for you and with you."

In order to develop and maintain this spirit, consideration was given to every detail of our operations in the light of employee reaction. Meetings were held to discuss the improvement of performance, and many suggestions were received which materially improved the operation of the Exhibit.

Trips "Behind the Scenes"

WHENEVER visitors wished to see the mechanical equipment, a technical man was called who escorted visitors behind the scenes and explained the operation of the equipment. During the 254 days of the Fair the mechanical equipment was shown to more than 4,000 people. Each group averaged about 2.2 persons and the average time required for the explanation was 22 minutes. These technical excursions elicited many favorable comments from the visitors.

To lessen formality and aid in creating a friendly atmosphere, regular uniforms were not provided. Instead, tailored dresses for women and business suits for men, uniform in character, were furnished. The women were fitted with a French blue serge dress and bolero with navy blue collar and cuffs. The men's suits were conservative double-breasted cadet gray worsted. Pages wore single-breasted suits of brown serge.

The dresses worn by our young ladies attracted much favorable comment, such as:

"Your uniforms are the most attractive at the Fair. The whole force makes a marvelous appearance."

"I certainly like your dresses. Will you please tell me where you had them made so that I may get the pattern?"

Particular attention was given to the reception and entertainment of members of our own and other Bell System companies. The Exhibit personnel realized and attempted to convey to these visiting telephone people that we were not only happy to see them but also we felt that this was their Exhibit; in other words, that we were conducting the demonstrations in their interests. We not only explained the Exhibit to them and urged them to participate, but, whenever they showed a desire, we took them back of the scenes and explained the mechanical equipment and set-up.

THE comments which we received from visitors orally and by letter convince us that we accomplished, in a large measure, through the Exhibit the results we sought. A few of the oral comments follow:—

The president of a large trust company of New York stated that the thing which impressed him about our Exhibit was the friendly, helpful atmosphere that was felt as one entered the Exhibit.

One lady approached a receptionist and said, "I have not been here for some time but it is nice to see all you girls still with a smile."

A man in the hotel business told us he could not understand how it was our girls were so promptly on the job all the time, constantly smiling, and willing to give prompt, pleasant, courteous and accurate answers to all questions, until he noticed that we moved

SOME OF THE SEVENTY

Smiling and alert, this group is typical of the entire Exhibit staff

them from position to position so they did not get stale on any one position.

Following are excerpts from some letters of commendation which we have received:—

"May I also add that the very nature of your Exhibit, with the aid of your pleasing staff of employees, creates an air of friendliness and a spirit of good will not equaled elsewhere on the Island."

"To me this would seem to epitomize the spirit of The Pacific Telephone and Telegraph Company—that of personal service, personal interest, personal responsibility."

"Words are paltry to express my gratitude to you for this great favor. Your own pleasure in the knowledge of one more service for humanity must be the greatest satisfaction you can know."

"May I express my complete and sincere gratitude for your excellent service, courtesy and graciousness."

"This kindness and joy is being spread like the crumbs of bread which were cast upon the water and will return in the future."

"I have never written a fan letter. Many times I have been tempted to when I encountered something particularly outstanding, but this time I cannot ignore the urge to write. I have never in all my experience, and I have gone much and far, enjoyed such courtesy as I have from each and every one connected with your Exhibit at Treasure Island. It makes the heart thrill to find everyone so eager to be helpful."

"I was so very much impressed at the pleasant, efficient service and courtesy I received from the time my number was called until the call was com-

pleted. I realized the thousands of calls that had been made before mine, yet each person that was necessarily contacted to complete the call seemed as happy and interested as I—and certainly explained why the Bell Telephone Company is the huge company and success it is."

"It is indeed difficult to understand how any group of workers can labor with and endure the foibles of a conglomerate public for hours at a time and still retain such a pleasant attitude. The treatment I have personally received at your Exhibit will always be remembered as the high light of the Fair."

"I believe that I was in a proper position to judge your employees last Sunday, and every one of them, from the manager to the messenger boys, were outstanding for their politeness and their desire to be helpful."

"The young ladies are very charming and kind and the managers go out of their way to be courteous. We intend to visit your exhibit again soon and until then many, many felicitations for the finest exhibit at the Golden Gate Exposition."

THE closing night reminded one of graduation day at school. Nine months had been spent by the personnel in close association, coöperating to build through the Exhibit a greater appreciation on the part of the public for the "Spirit of Service" which actuates the Bell System. After the last visitor had left, the personnel assembled in the Voder room for goodbyes. Our job was done and we were about to separate, to continue this same spirit on our regular assignments.

Amidst tears and laughter, N. R. Powley, President of The Pacific Telephone and Telegraph Company, which operated the Exhibit, expressed appreciation to the personnel for their splendid achievement. Telegrams of commendation from Walter S. Gifford, President of the American Telephone and Telegraph Company; A. W. Page, Vice President of the American Telephone and Telegraph Company; and John Mills, Director of Publication of the Bell Telephone Laboratories, were read.

There is no better way to summarize the accomplishments of the Exhibit than to quote the message from Mr. Gifford:

"I want to express to you and your associates my congratulations and thanks for the splendid way with which you have handled the Bell System Exhibit. Its outstanding success has been a great satisfaction to us all."

THE QUARTERLY IN NEW DRESS

THE changes which are evident in the format and typography of this issue of the BELL TELEPHONE QUARTERLY have been made in the interests of easier reading and more pleasing appearance. Its editorial policy, of serving the Bell System as "a medium of suggestion and a record of progress," remains unchanged.

CONTRIBUTORS TO THIS ISSUE

THE degrees of B.A., A.M., and B.S. were conferred on JOHN MILLS by, respectively, the University of Chicago in 1901, the University of Nebraska in 1903, and Massachusetts Institute of Technology in 1909. The intervening years he occupied in study, and in teaching at those and other institutions of learning. In 1911 he joined the Engineering Department of the A. T. and T. Company. In 1915 he transferred to the Research Group in the Engineering Department of the Western Electric Company. From 1921 to 1925 he served as assistant personnel director and personnel director for the Engineering Department. With the incorporation of the Bell Telephone Laboratories in 1925, he was made Director of Publication, which office he now holds. In addition to numerous textbooks on scientific subjects, he is the author of "A Fugue in Cycles and Bels" and "Signals and Speech in Electrical Communication."

After attending Washington University, St. Louis, Mo., HORACE H. NANCE joined the St. Louis staff of the Long Lines Department of the A. T. and T. Company in 1910 as equipment attendant. In 1916 he went to Denver as district plant chief, and two years later was transferred to Washington, D. C. After absence in military service, he rejoined the Long Lines Department as a technical employee in New York. In 1919 he was appointed division superintendent of equipment construction at Chicago. A year later he was made division plant engineer in Atlanta, and in 1922 was transferred to Philadelphia in the same capacity. He was made Engineer of Transmission in New York in 1924, and in 1928 was appointed to his present post of Plant Extension Engineer.

Stevens Institute of Technology graduated ROBERT M. ORAM with the degree of B.S. in M.E. in 1913. The following year he joined the Long Lines Department of the A. T. and T. Company. Two years later he resigned, but after war service and private occupation he rejoined the Long Lines Department in 1919. Until 1925 he held various plant engineering assignments in New York. He was then division transmission engineer, division outside plant engineer, division supervisor of cable construction, and division construction superintendent, in New York. Transferred to Philadelphia, he was division plant engineer and division plant superintendent there from 1928 to 1936. In the latter year he returned to New York as General Plant Supervisor, his present position.

It was in 1904 that FRANK B. JEWETT left the teaching staff of Massachusetts Institute of Technology to join the Engineering Department of the A. T. and T. Company. He had been graduated from Throop Polytechnic Institute (now California Institute of Technology) with the B.A. degree in 1898, and had received his Ph.D. degree from the University of Chicago in 1902. From 1908 to 1912 he was transmission and protection engineer of the A. T. & T. Co. In the latter year he was transferred to the Western Electric Co. as Assistant Chief Engineer, and became Chief Engineer of the company in 1916 and Vice President in 1922. In 1925 he was elected Vice President of the A. T. & T. Co., and in the same year was made President of Bell Telephone Laboratories Inc.—which offices he now holds. He was awarded the Distinguished Service Medal for his work during the World War; has received a number of honorary degrees, medals, and awards; and is active in numerous educational and scientific organizations. Last April he was elected President of the National Academy of Sciences.

Graduated from Bowdoin College with the B.A. degree in 1910, THOMAS W. WILLIAMS was employed in the traffic department of the New England Tele-

phone and Telegraph Company the same year. Six years later he transferred to the Traffic Department of the Long Lines Department of the A. T. and T. Company. From 1920 to 1929 he was with the Traffic Department of the New York Telephone Company, and in the latter year transferred to the Commercial Department. In 1938 he was appointed Director of the Bell System Exhibit at the New York World's Fair.

Entering the Pacific Telephone and Telegraph Company in 1908, LAURENCE N. ROBERTS was engaged in Plant Department work until 1915. Attendance at the University of Nevada, and military service, then occupied him for four years. He rejoined the Pacific Company in 1919, and until 1936 was employed in the Plant and Commercial Departments. In the latter year he was made Educational Supervisor, and in 1938 was appointed Manager of the Bell System Exhibit at the Golden Gate International Exposition.

FOR THE RECORD

C. G. STOLL SUCCEEDS E. S. BLOOM AS WESTERN ELECTRIC HEAD

EDGAR S. BLOOM retired as President of the Western Electric Company on December 31. Elected as his successor was Clarence G. Stoll, who since 1928 has been Vice President in charge of Operations.

Mr. Bloom's retirement brings to a close a distinguished telephone career. Upon receiving a post-graduate degree in mechanical engineering from the University of Pennsylvania in 1896, he started as a traffic inspector with the Metropolitan Telephone and Telegraph Company, predecessor of the New York Telephone Company. Within ten years he was Plant Superintendent of the New York and New Jersey Telephone Company. Three years later he moved to the Pacific Telephone and Telegraph Company in a similar capacity, and in 1910 was placed in charge of plant operations for the A. T. and T. Company. Two years later he was made Operating Vice President of a group of Bell companies in the Southwest. Appointed receiver for the Central Union Telephone Company at Chicago in 1914, he brought about a successful reorganization and later became President of the Ohio and Indiana Bell Telephone Companies and Vice President of the Illinois Bell Telephone Company. In 1922 Mr. Bloom came to New York as Vice President of the A. T. & T. Co. In 1926 he was elected President of the Western Electric Company.

Mr. Stoll graduated from Penn State in 1903 and entered Western Electric's student training course in Chicago. By 1908 he had become Engineer of Methods and later head of the manufacturing branch in New York. Summoned abroad in 1912, he acted as shop superintendent in the company's Antwerp factory until the World War forced the shop to close. Returning to the United States, he rose through various supervisory posts in manufacturing and technical operations at the Hawthorne Works in Chicago and in 1923 was placed in charge of the Works. He came to New York three years later and was elected Vice President in charge of Manufacturing and a director of the company. Since 1928 he has been Vice President in charge of Operations.